

RED STAR



VOLUME 23

Soviet/Russian AWACS Aircraft

Tu-126, A-50, An-71 and Ka-31



Yefim Gordon and Dmitriy Komissarov

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Tu-126, A-50, An-71 and Ka-31



**Yefim Gordon
and Dmitriy Komissarov**


MIDLAND
An imprint of
Ian Allan Publishing

Soviet/Russian AWACS Aircraft

© 2005 Yefim Gordon and Dmitry Komissarov

ISBN 1 85780 215 2

Published by Midland Publishing

4 Watling Drive, Hinckley, LE10 3EY, England

Tel: 01455 254 490 Fax: 01455 254 495

E-mail: midlandbooks@compuserve.com

Midland Publishing is an imprint of

Ian Allan Publishing Ltd

Worldwide distribution (except North America):

Midland Counties Publications

4 Watling Drive, Hinckley, LE10 3EY, England

Telephone: 01455 254 450 Fax: 01455 233 737

E-mail: midlandbooks@compuserve.com

www.midlandcountiessuperstore.com

North American trade distribution:

Specialty Press Publishers & Wholesalers Inc.

39966 Grand Avenue, North Branch, MN 55056, USA

Tel: 651 277 1400 Fax: 651 277 1203

Toll free telephone: 800 895 4585

www.specialtypress.com

Design concept and layout by
Polygon Press Ltd (Moscow, Russia)

Line drawings by Andrey Yurgenson

Colour artwork by Andrey Yurgenson and

Sergey Yershov

This book is illustrated with photos by Yefim Gordon, Dmitry Komissarov, Sergey Komissarov, Victor Drushlyakov, Vyacheslav Martyniuk, Sergey Panov, Sergey Sergeyev, Sergey Skrynnikov, Peter Davison, ITAR-TASS, as well as from the archives of the Tupolev JSC, TANTK Beriyev, ANTK Antonov, Kamov Helicopters, the Gromov Flight Research Institute, the US Navy, the Royal Norwegian Air Force, Yefim Gordon, and Sergey and Dmitry Komissarov.

Printed in England by Ian Allan Printing Ltd
Riverdene Business Park, Molesey Road,
Hersham, Surrey, KT12 4RG

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Title page: The second prototype Ka-31, '32 Blue' (formerly '032 Blue' – note the painted-out zero), with the radar antenna deployed.

This page: CCCP-780151, the first prototype An-71, taxis at Kiev-Svyatoshino with the flaps at take-off setting. Note that the starboard engine's thrust reverser is partially deployed.

Front cover: A-50U '51 Red' (c/n 1003488634) makes a smoky final approach to Ivanovo-Severnnyy AB.

Rear cover, top: An-71 CCCP-780361 at Kiev-Svyatoshino; bottom: Indian Navy Ka-31 '565' at the Aero India-2004 airshow in Bangalore.



Introduction

Surprise was always one of the key elements of success during offensive air operations, be it counter-air, bombing/attack or reconnaissance missions. Accordingly, it was vital for those on the receiving end to learn of the enemy's approach in advance so as not to receive such nasty surprises. Originally the side being attacked had to rely on pickets with human observers and telephone or radio communication. The development of radar technology made possible the advent of radar picket ships; the next obvious step was to develop a technology initially known as airborne early warning (AEW). A key function of such flying radar pickets – control of 'friendly' fighters or strike aircraft – soon led the designation to be amended to airborne early warning and control (AEW&C) or airborne warning and control system (AWACS).

Development of AEW aircraft began in earnest after the Second World War. Initially the USA and Great Britain were the main developers and users of this technology.

Generally AWACS aircraft can be divided into two categories: shore-based and shipboard. The latter are primarily intended for protecting aircraft carriers, which are vulnerable and lucrative targets, and other ships. The small dimensions of such aircraft occasioned by below-deck stowage requirements impose a limit on the fuel capacity (and hence endurance), number of mission crew and thus limit their capabilities. The shore-based ones, on the other hand, are unencumbered by space limitations and can be based on transport aircraft or airliners, offering room for more fuel and a relief crew.

Carrier-based AEW aircraft development began in the USA with the Grumman TBM-3W equipped with an APS-20 search radar in a ventral 'guppy' radome. A similar installation found use on the later Douglas AD-3W, AD-4W and AD-5W Skyraider produced in the late 1940s/early 1950s (the latter model became the EA-1E in 1962 when the US Navy changed its designation system). These were the first AEW aircraft to see action (in the Korean War), and the AD-4W was also supplied to the Royal Navy which operated it as the Skyraider AEW.1 from 1952. Later, the British aircraft industry brought out the Fairey Gannet AEW.3 featuring a similar 'guppy' radome which first flew on 20th August 1958.

Meanwhile, in 1954 Grumman began development of a more capable shipboard AEW aircraft based on the S2F-1 Tracker (later known as the S-2A) anti-submarine warfare aircraft. The machine that eventually entered flight test in 1957, however, was based on the Tracker's carrier on-board delivery (COD) derivative, the TF-1 Trader (C-1A), and was designated WF-2 Tracer, later changed to E-1. This aircraft introduced the dorsal radar antenna placement typical of modern AWACS aircraft, the antennas being housed inside a huge strut-mounted fixed 'dish'. In the meantime, however, the US Navy's growing requirements led to the emergence of a new Naval Tactical Data System (= AWACS) resulting in the development of the Grumman W2F-1, which has the distinction of being the first-ever 'clean sheet of paper' AWACS. Redesignated E-2A Hawkeye, this twin-turboprop aircraft, which first flew on 21st October 1960 and entered service in 1964, was a major improvement on the piston-engined Tracer. It had the radar antennas mounted in an unmistakable saucer-shaped revolving housing – a so-called rotodome.

At the other end of the scale, Lockheed Aircraft brought out a radar picket version of the L-749 Constellation airliner in 1949. Designated PO-1W (later WV-1), this aircraft had huge radomes above and below the fuselage and a mission crew of 22. A more advanced version, based on the L-1049 Constellation, followed in 1953 as the WV-2 Warning Star, featuring more powerful engines and a bigger mission crew. Redesignated EC-121K in 1962, this aircraft was built in considerable numbers and was used to set up Early Warning Barriers over the Atlantic and Pacific. It also saw action in the Vietnam War, controlling the actions of US Navy fighters. A single example was modified as the WV-2E (EC-121L) with a dorsal 'saucer' radome.

A successor to the Warning Star was developed by Boeing, using their 707-320B four-turboprop airliner as the basis. Originally known as the EC-137D and subsequently redesignated E-3A Sentry, this aircraft first flew on 9th February 1972 and entered service in 1977. It had a rotodome mounted on twin pylons aft of the wings. A succession of versions with ever more capable avionics



Above: A US Air Force Lockheed EC-121C Warning Star serialised 51-3836, showing the characteristic dual radomes and the equally characteristic triple tails of the Constellation airliner on which it is based.



A Grumman E-1B Tracer (known in US Navy slang as 'Willy Fudd', or 'Stoof with a Roof') pictured on short finals to an aircraft carrier; note the extended arrestor hook. The huge size of the radome is obvious.



Above: Grumman E-2C+ Hawkeye BuNo 163849 (c/n A136) operated by the Naval Air Weapons Center (NAWC) approaches the runway at Farnborough in July 2002. Note the 'tripod' carrying the rotodome.



An upper view of the world's best-known AWACS – the Boeing E-3A Sentry. Note that the greater part of the rotodome is dielectric.

and, later, new CFM56-2A2 engines were brought out, and apart from the USAF the type saw service with NATO's AEW Force in Europe, the Royal Air Force (E-3D), the French *Armée de l'Air* (E-3F) and the Royal Saudi Air Force. As a successor to the Sentry, whose basic design is showing its age after all, in 1991 Boeing developed the E-767 – an AWACS derivative of the Boeing 767-200ER twin-turboprop airliner with a windowless fuselage and a rotodome. The type entered limited production in 1992, but so far the only customer is the Japan Air Self-Defence Force.

Smaller airliners have also been adapted for AEW&C duties. These include the Swedish SAAB 340AEW (S-100B Argus) and the Brazilian Embraer EMB-145AEW, both of which have an Ericsson Erieye phased-array radar in a strut-mounted pod above the fuselage; the RAF's ASTOR (Airborne Stand-Off Radar) based on the Bombardier Global Express business jet; and the Wedgetail based on the Boeing 737-700 for the Royal Australian Air Force. Helicopters, too, have been adapted for AEW duties, the best-known model being the Westland Sea King AEW.2 and AEW.7 (later redesignated ASaC.7 – Airborne Surveillance and Control) which took over from the Gannet AEW.3 in Royal Navy service.

However, all of this took place on one side of the Iron Curtain. What was going on in the meantime on the other side, you may ask? Well, the 'iron' bit is just a figure of speech, of course; the Soviet political and military leaders were reasonably well informed on military technology development in the West at all times – and on the strengths and flaws of their own national air defence system, too. For many years the northern reaches of the Soviet Union were protected from attack by the vast expanse of the Arctic Ocean. However, as the West developed more capable offensive weapon systems, the northern and Far Eastern regions of the USSR were no longer safe. Building and operating airbases and air defence (AD) radar systems in those inhospitable parts was a major problem. Therefore, the Soviet Air Force (VVS – *Voyenno-vozdoozhnyye seely*) and the Air Defence Force (PVO – *Protivovozdooshnaya oborona*) needed airborne early warning and control assets comparable in their capabilities to those developed in the West. This book charts how the Soviet, and later Russian, aircraft industry tried to cope with this task, with varying success.

Acknowledgements

The authors wish to thank Vladimir Rigmant who supplied some of the materials used in this book.

Tupolev's Contribution

Tu-126 AWACS Aircraft (*Izdeliye L*)

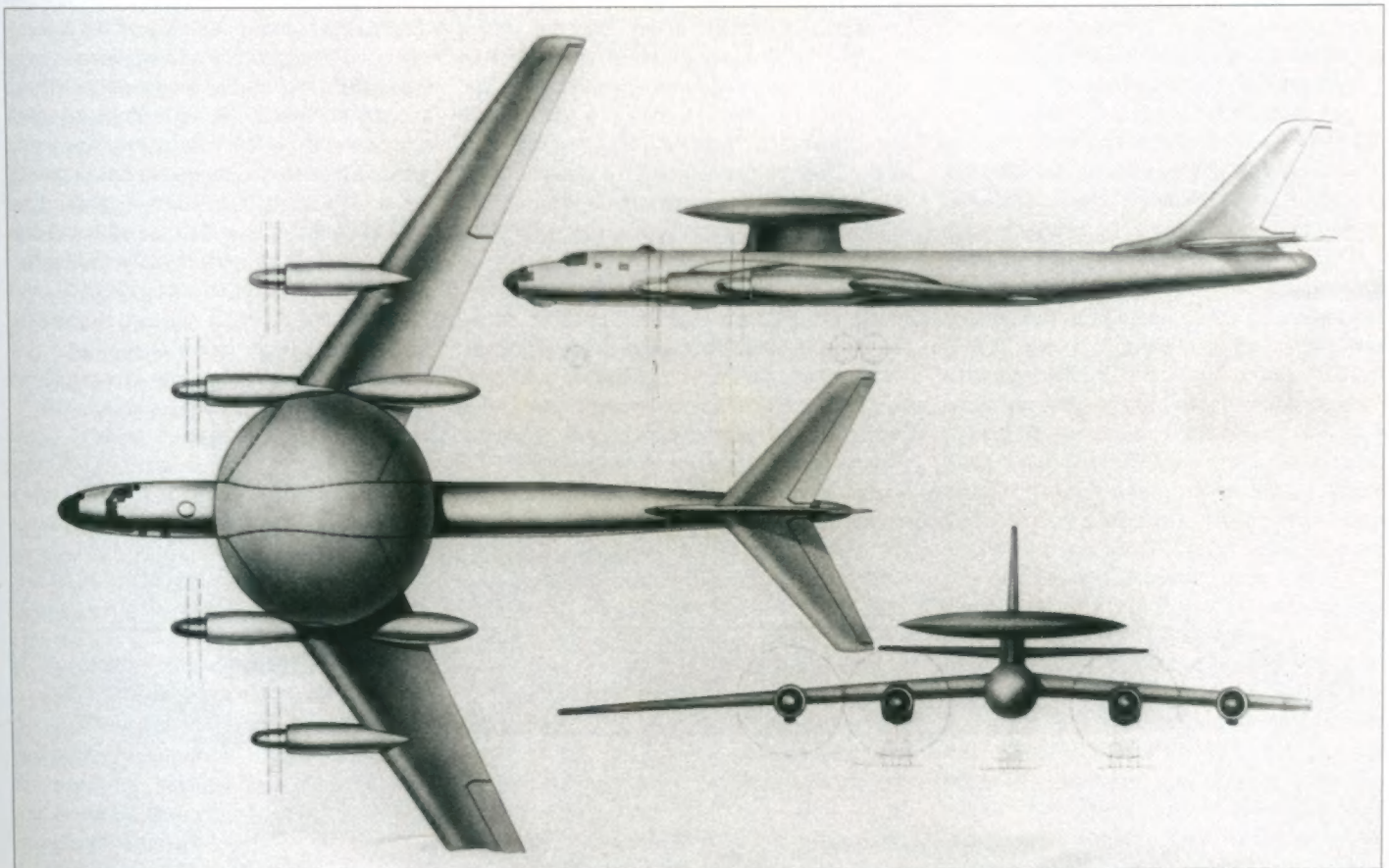
On 4th July 1958 the Soviet Council of Ministers issued directive No 608-293 tasking the Tupolev OKB with creating an airborne radar picket system. The aircraft was to utilise the newly-developed *Liana* (Creeper) radar and communications suite created by the Moscow Research Institute of Instrument Engineering (NII-17, or MNIIP – *Moskovskiy nauchno-issledovatel'skiy institut priborostroyeniya*) under General Designer V. P. Ivanov. Derived from the ground-based P-30 air defence radar, the Liana had phenomenal performance by the day's standards; it was optimised to detect airborne targets at medium to high altitudes at a range of 100-350 km (62-217 miles) and cruiser-sized surface ships over a range of 400 km (248 miles). It was also able to detect illumination by enemy radars at distances of 500-600 km (310-372 miles). Information could then be transmitted to PVO and VMF command cen-

tres up to 2,000 km (1,242 miles) away. Additionally, the system was compatible with all other communications and detection systems in the Soviet Union. It was determined that an air defence system required such capability if it was to be effective. The difficult-to-defend northern borders of Russia were particularly vulnerable to attack, and it was proposed that the Liana system could close that hole in the Soviet Union's air defence network.

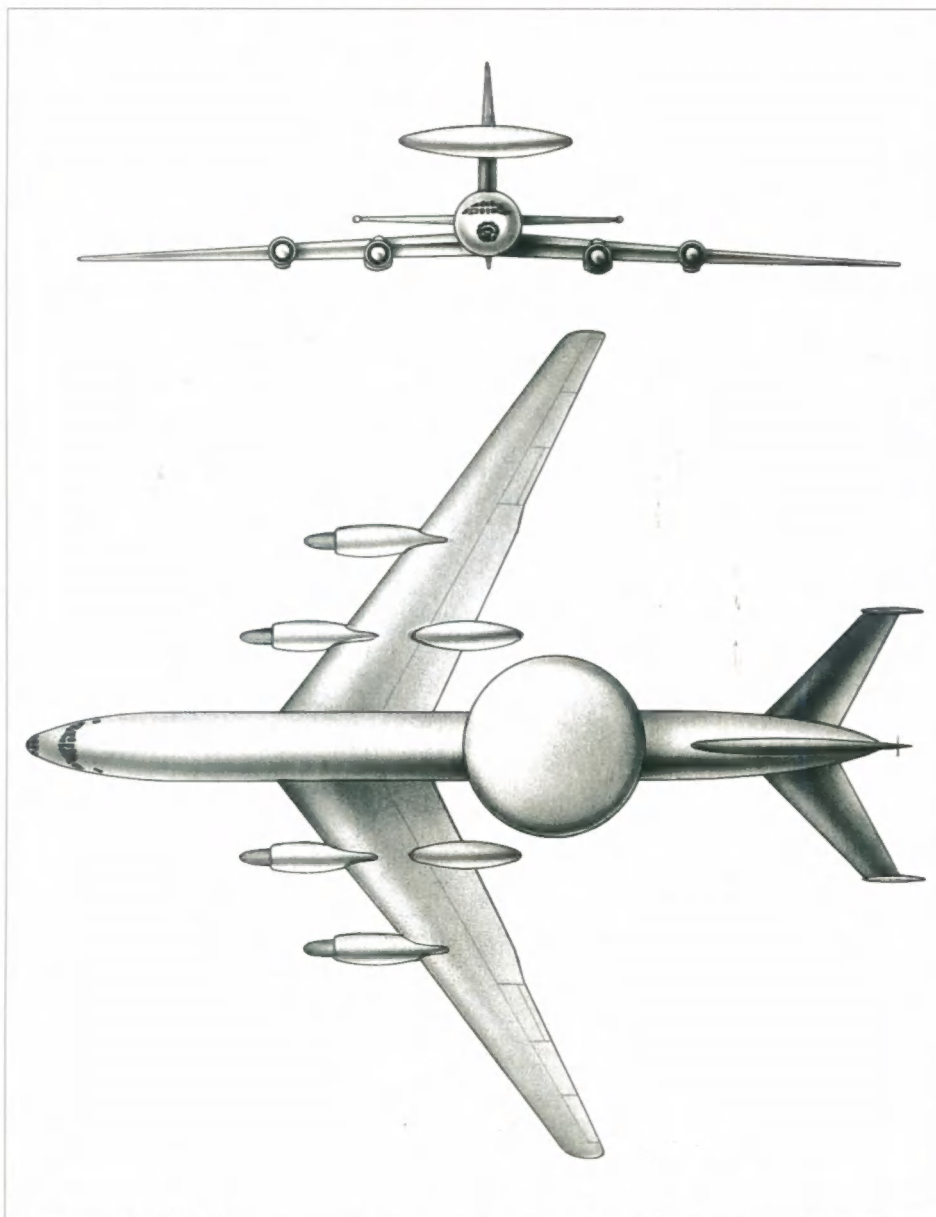
As the programme progressed, it was decided to make the Liana capable of detecting both airborne and surface targets. It was then determined that the mission would require long-duration flights, some in excess of 10 to 12 hours. Cruise altitude for the mission was to be between 8,000 and 12,000 m (26,240-39,360 ft). Detection range in the upper hemisphere (using line-of-sight computation) was to be 100 km (62 miles) for aircraft the size of the MiG-17 tactical fighter, 200

km (124 miles) for aircraft the size of the Il'yushin IL-28 tactical bomber and 300 km (186 miles) for aircraft the size of the Myasishchev M-4 strategic bomber. Detection range below the horizon was limited to only 20 km (12.4 miles).

Initial studies called for the modification of the Tu-95 four-turboprop strategic bomber to fill the picket role. However, analysis and calculations carried out in Sergey M. Yeger's section of the OKB showed that it was not viable to base the proposed AWACS aircraft on the Tu-95 due to the bomber's lack of interior volume for accommodating the mission equipment. On the other hand, the new Tu-114 *Rossiia* (Russia) long-haul airliner derived from the Tu-95 proved a near-perfect match for the Liana system and the mission. Therefore, in 1960 the Council of Ministers passed another directive requesting the Tupolev OKB to review the Tu-114 and assess



A three-view of the projected AWACS derivative of the Tu-95 bomber which was rejected due to the limited internal space. Note the position of the rotodome well forward on the fuselage for CG reasons; the rotodome is shown as 'translucent' in the plan view to show the wing/fuselage joint.



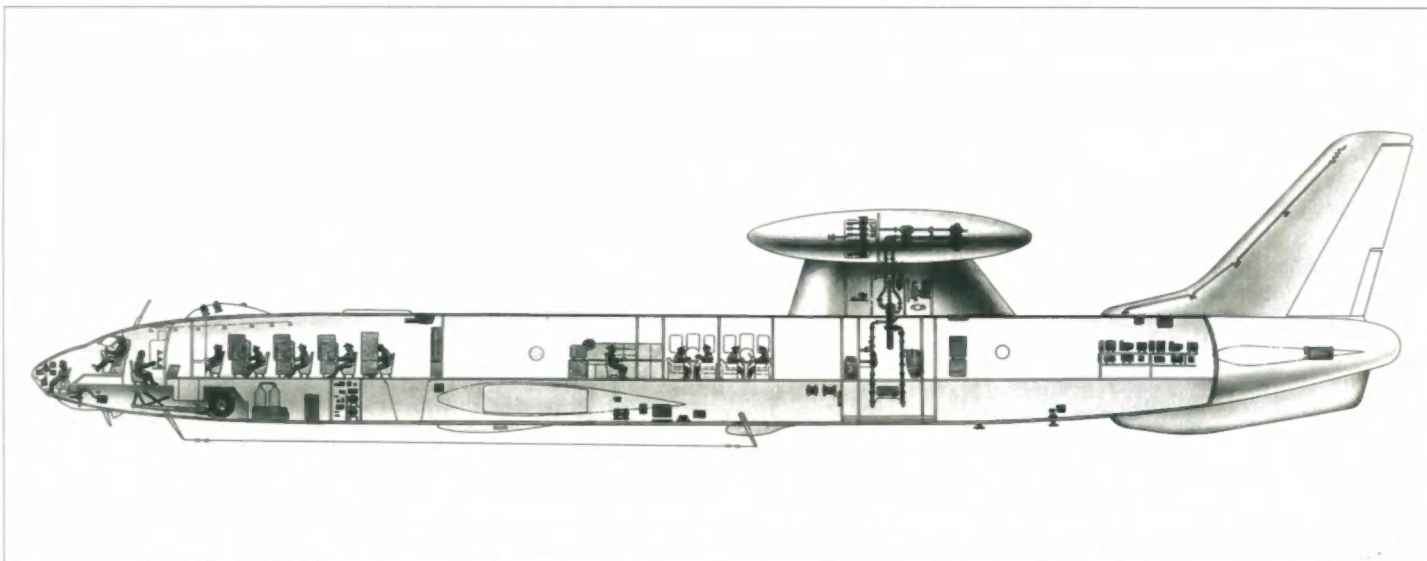
Above: Two views of the Tu-126 from the project documents, showing the more traditional placement of the rotodome.

its suitability as a platform for the Liana system. Tupolev came to the following conclusions:

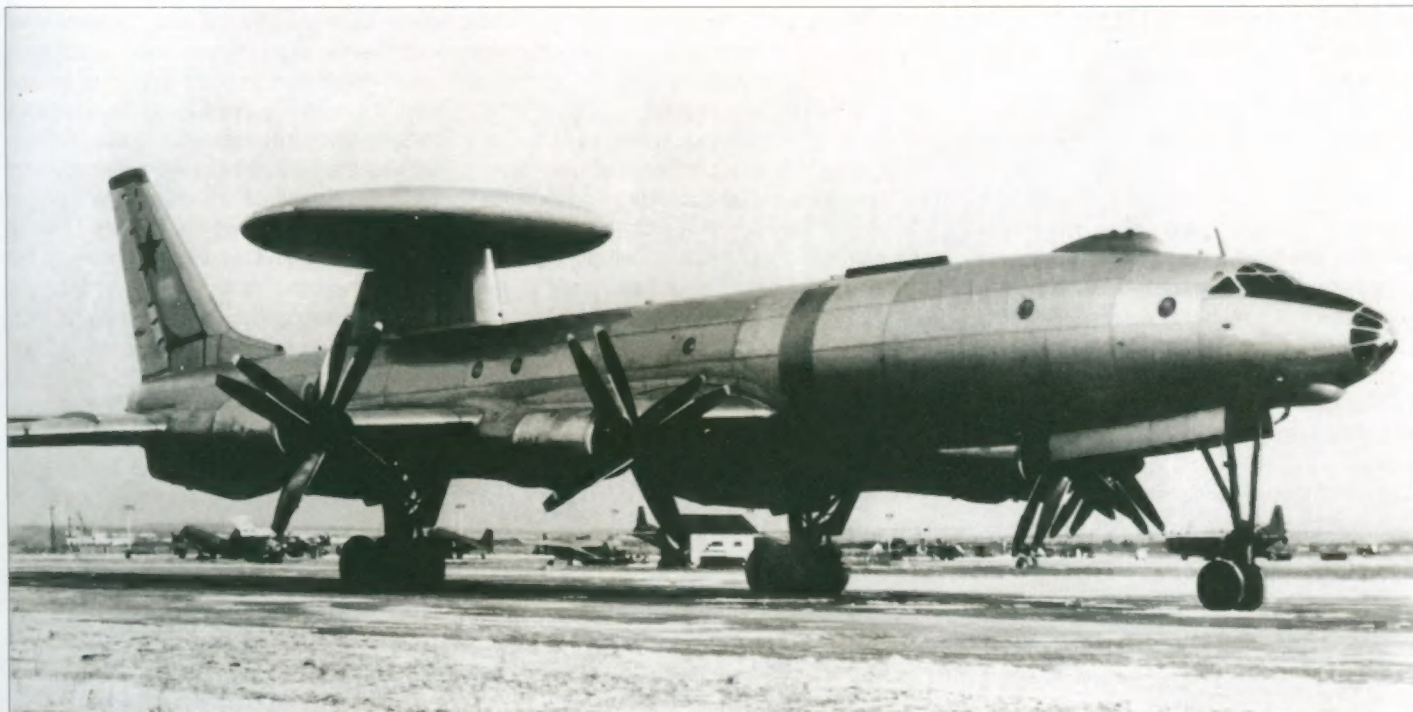
- the mission avionics would fit into the Tu-114's pressurised cabin without any problems and could be supported and maintained even while the aircraft was in flight;
- two full crews of 12 personnel each could be accommodated, thus allowing the Liana system to be manned around the clock;
- heat dissipation requirements – always a major concern when a lot of avionics are involved – could be accommodated within the Tu-114's airframe and existing systems.

The radar picket aircraft based on the Tu-114 was designated '126' (Tu-126) or *izdeliye L* ('product L'; the latter code was derived from the name of the Liana suite). Many difficulties were overcome in order to make the new system work, not the least of which was alleviating electromagnetic compatibility (EMC) conflicts between the various components making up the Liana suite.

One of the most challenging items during the course of the Tu-126's development was the choice of the optimum design and location for the radar's revolving antenna. Two options were explored by the Kuibyshev aviation factory No.18 (which built the Tu-114) and the Tupolev OKB. Both featured a lens-shaped fairing mounted on top of a dorsal pylon positioned about halfway between the wings and the vertical tail, resulting in a distinctive 'mushroom' structure. In the first version of the project the rotating antenna array was positioned inside a fixed dielectric fairing; the other utilised a rotating fairing (a so-called rotodome) of which the antenna was as an integral part. The latter option was proposed by A. I. Putilov, an aircraft engineer best known for his pre-war Stal'-2 and Stal'-3 passenger aircraft, who then headed the Tupolev OKB's branch office at factory No.18.



A cutaway drawing of the Tu-126, showing the mission crew's workstations at the front and the equipment racks in the centre and rear fuselage.



The Tu-126 prototype (c/n 61M601). The teardrop fairing aft of the flightdeck houses the celestial navigation system's star trackers. The dark area ahead of the wing leading edge is a skin reinforcement panel in the inboard propellers' plane of rotation protecting the skin against pieces of ice shed by the props.

It was eventually determined that the rotodome would be the best option; detailed studies had shown that this approach resulted in a lighter and stronger structure. Accordingly, a fairing large enough to accommodate the 11-metre (36 ft 1 in) antenna was developed. The rotodome was 2 m (6 ft 6 $\frac{1}{2}$ in) deep and the pylon was 2.6 m (8 ft 6 $\frac{3}{4}$ in) tall. The Tu-126 was the world's first aircraft to feature a rotodome. Unlike later AWACS aircraft utilising this arrangement, the pylon was single, not dual; it was very thick and had a very long chord. Only about one-third of the rotodome was dielectric, the rest being the supporting metal structure. The antenna rotated at 10 rpm. A large ventral fin was added to improve directional stability, offsetting the destabilising influence of the rotodome assembly.

An amusing episode occurred at this stage. Wishing to illustrate his idea, Putilov took a newspaper featuring a photo of the Tu-114 and pencilled in the proposed rotodome. A while later the Kuibyshev factory's security chief saw the 'retouched' photo and hit the ceiling, assuming that highly sensitive information had leaked into the press. It took a while to convince him that the artist's impression had been made on the spot.

One big problem was to obtain the huge bearings of 1,200 mm (3 ft 3 $\frac{3}{8}$ in) diameter needed for the rotodome. Such bearings did not exist until, through Tupolev's influence and energy, a Moscow factory succeeded in manufacturing them.

In general, the Tu-126 differed little from the Tu-114. Apart from the rotodome 'mush-

room' and the ventral fin, the airframe incorporated only minor structural changes. Outwardly the only other changes were the deletion of most of the cabin windows and the addition of miscellaneous fairings over navigation, communications and ECM equipment. Among other things, a teardrop-shaped metal fairing housing the navigation system's star trackers was located dorsally aft of the flightdeck, with a strake aerial aft of it. A heat exchanger fairing was located under the rear fuselage in line with the rotodome pylon's leading edge. Prominent cigar-shaped fairings were mounted at the tips of the horizontal tail, as on the Tu-95RTs over-the-horizon targeting/maritime reconnaissance aircraft; these housed the antennas of the *Leera* (Lyre) data link system. Virtually all other differences, including communications equipment, the cabin configuration and the mission equipment operating panels, were internal.

The former passenger cabin was entirely remodelled. The forward and central fuselage sections were occupied by control panels and the operators' workstations, while the rear section housed the surveillance radar and communications equipment. Two complete crews were provided. The flight crew consisted of two pilots, two navigators, a radio operator and a flight engineer. The mission crew comprised an intercept officer, three radar display station operators, an ECM/ESM equipment operator and a maintenance engineer to repair any faulty equipment in flight. Both aircrew and radar crew worked in shifts, as the aircraft was to remain airborne for 11 hours with a maximum range

of 7,000 km (4,347 miles). The off-duty crew had at its disposal a rest area equipped with bunks and a restroom.

Since the powerful radar and other equipment generated harmful high-frequency radiation, special precautions were taken to protect the crew from the various electromagnetic energy sources in the Tu-126. Radiation shielding was applied where appropriate.

The original design studies called for the aircraft to have a tail gun turret with two 23-mm (.90-calibre) Afanas'yev/Makarov AM-23 cannons aimed by means of a TV sighting system and a PRS-1 Krypton gun-ranging radar for defence against enemy fighters. This was shelved in favour of installing a powerful passive/active electronic countermeasures (ECM) system. Additionally, the aircraft was equipped with a probe-and-drogue in-flight refuelling (IFR) system which would permit it to stay on station for virtually unlimited periods of time. The IFR probe was located immediately ahead of the flightdeck glazing, above the navigator's station in the extreme nose.

For two years work on the system did not proceed beyond research studies. At last, in early 1960, the Air Force agreed that the Tu-126 should be based on the Tu-114. On 30th January 1960 a draft proposal calling for hardware development of the new AWACS aircraft based on the Tu-114 airliner was approved. On 30th May 1960 the Council of Ministers released the official directive No.567-230 naming the Kuibyshev aircraft factory as the site where the Tu-126 prototype would be built. In August 1960 confirmation was received and in December a mock-up

review met with favourable results. According to plans, the prototype would be ready for flight test by the fourth quarter of 1961.

The work at Kuibyshev was supervised by A I Putilov. The first prototype (c/n 61M601 – that is, year of manufacture 1961, Tu-126 (in-house product designator M6), Batch 0, 1st aircraft in the batch; the same system was used for late-production Tu-114s) was completed approximately on schedule and by the end of 1961, it was being readied for start of the flight test programme. Marked '618601' on the nose, on 23rd February 1962 the first Tu-126 took to the air for the first time from the Kuibyshev factory's Bezymyanka airfield with Tupolev OKB chief test pilot Ivan M Sookhomlin in the captain's seat; the crew also included co-pilot Lipko, navigators Roodnev and Iksanov and flight engineer Dralin. Engineer N. V. Lashkevich, who had survived the crashes of the Tu-85 and Tu-95/1 bomber prototypes, was in charge of the tests.

The tests were not altogether without problems. The huge 'saucer' of the rotodome and the rearward shift of the CG changed the aircraft's handling considerably as compared to the Tu-114. For instance, when the flaps were retracted after take-off the Tu-126 had a tendency to sway fore and aft for a while before stabilising in the climb; this 'seesawing' was not mortally dangerous, but nevertheless unnerving. The drag generated by the rotodome created a considerable pitch-up force, which depended on the flight speed and complicated the flying technique. The drag also had its effect on the aircraft's speed; the Tu-126 was 100 km/h (62 mph) slower than the Tu-95. Furthermore, electromagnetic compatibility problems with the mission avionics began; the avionics utilised vacuum tubes, and Soviet electronic components of the day were notoriously unreliable.

A few spills also occurred. Thus, on 18th June 1964 the prototype's nose gear unit would not retract as the machine departed Lookhovitsy (Tret'yakovo airfield) on a test mission up north. A visual check showed that the strut was stuck halfway through retraction. The emergency extension system had to be brought into play and the mission was aborted. On another occasion someone suggested gluing foam rubber pads to the rear fuselage sides to prevent ice formation at the roots of the variable-incidence stabilisers. As the fuselage flexed in flight, these rubber pads warped and jammed the stabilisers in fully nose-down position, nearly causing a crash. The rubber was subsequently replaced by slippery Textolite composite.

Joint state acceptance trials of the Tu-126 and its Liana system were undertaken by the OKB and the Soviet Air Force in two stages. Stage A was completed successfully on 8th February 1964 – largely due to the tremen-

dous dedication of the people involved. It was concerned with refining the Liana suite and testing it for compatibility with the aircraft's other systems and equipment. Stage B, which was completed during November 1964, included testing the compatibility of the Tu-126 and the Liana system with ground-based and shipboard air defence systems and command, control and communications (C³) centres. Of particular concern was the ability of the aircraft to transmit data to surface receivers in high-countermeasures environments and in combat conditions. General Podol'skiy, who chaired the State commission holding the trials, did a lot to see the objective completed. For instance, it took his intervention to make sure that the test engineers, who initially had to fly their missions in ordinary civilian clothes, were issued proper flying suits.

Nearly two years were required to verify the system's capabilities and limitations. In August 1963, even as the testing proceeded, a decision was made to move ahead with Tu-126 production. However, because several important tests pertaining to the Liana system's viability had not yet been completed, the aircraft was not actually placed into production until early 1965.

Due to the very special mission fulfilled by the aircraft the Tu-126's production run was extremely limited. Eight production aircraft were manufactured between 1965 and 1967. Two batches were built, Batch 1 comprising three aircraft (c/ns 65M611, 65M612 and 66M613) and Batch 2 consisting of five machines (c/ns 66M621 and 67M622 through 66M625). After the cessation of production the Tu-126 and its Tu-114 commercial predecessor were superseded on the assembly lines at factory No.18 by the Tu-154 three-turbofan airliner and the Tu-142 long-range anti-submarine warfare aircraft (which, like the Tu-114 and Tu-126, was a direct descendant of the Tu-95).

Outwardly production Tu-126s differed from the prototype in having oblong dielectric fairings the rear fuselage sides in line with the rotodome pylon's trailing edge in the manner of the Tu-95KD/Tu-95KM missile strike aircraft, with two ventral dielectric blisters positioned in tandem fore and aft of the lateral fairings; these housed electronic intelligence (ELINT) system antennas. The ventral heat exchanger fairing was made more compact and repositioned further forward; the cabin window arrangement was also different.

During the production run, improvements in ECM systems were introduced and other changes were added to new aircraft as they rolled off the assembly line. Thus, c/n 65M612 and the last four examples built in 1967 featured an extended ogival tailcone housing an SPS-100 *Rezeda* (Mignonette) active jammer; this supplanted the chaff dispensers fitted to

earlier examples. Production machines were also used in test programmes; for instance, c/n 66M622 was used to verify the in-flight refuelling procedures, using Myasishchev 3MS2 tankers. This was no easy task; it turned out that the Tu-126 behaved differently from the Tu-95 in the tanker's wake vortex.

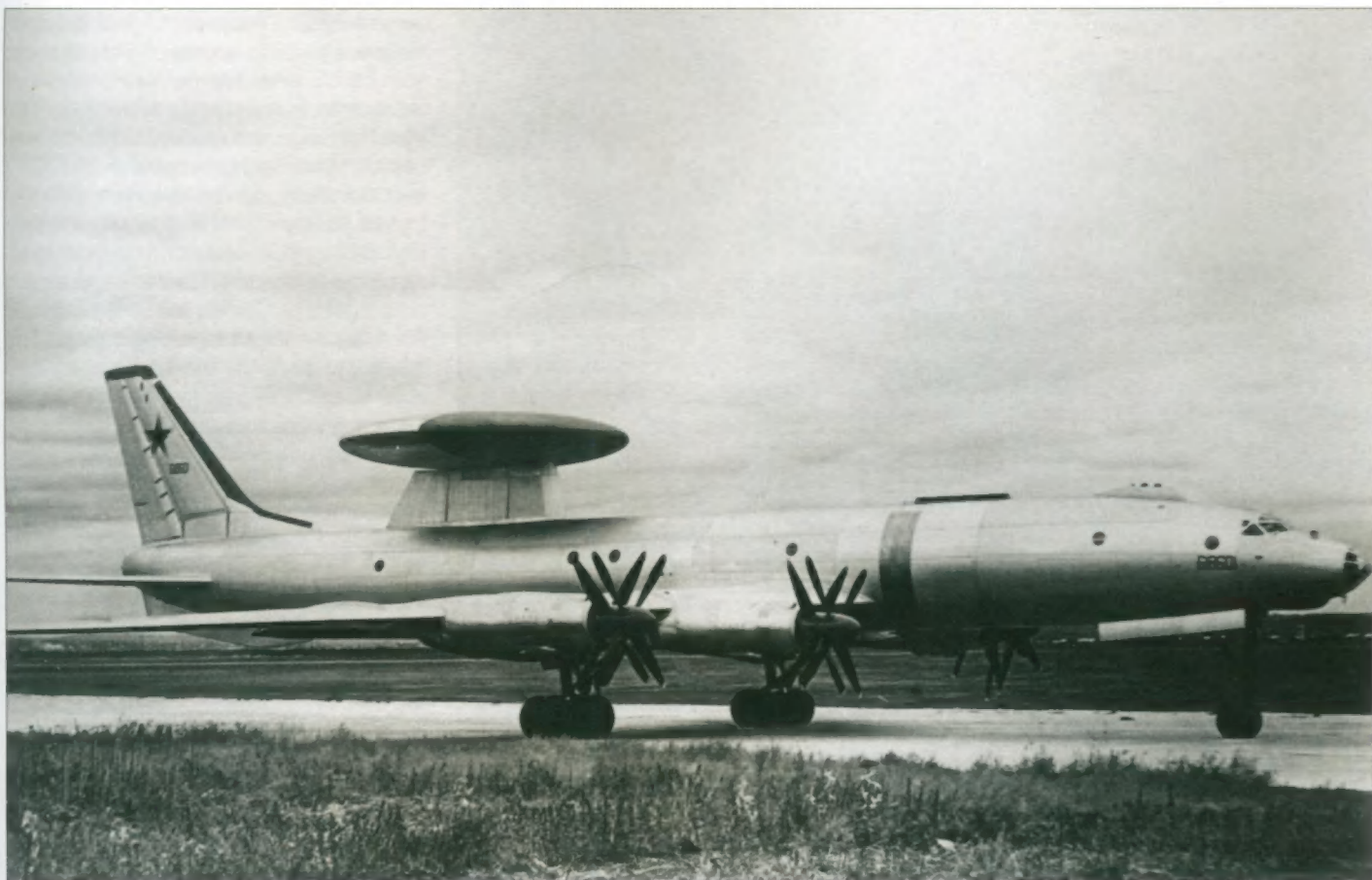
On 30th April 1965 the Council of Ministers passed a directive formally including the Tu-126 into the PVO inventory. The type equipped a single squadron – the 67th Independent Airborne Early Warning Squadron based not far from Siauliai (pronounced '*Shaooliay*'), Latvia. The aircraft soon became known to the Western world, and the NATO's Air Standards Co-ordinating Committee (ASCC) allocated the reporting name *Moss* (in the 'miscellaneous aircraft' category) to the Tu-126.

The advent of the Tu-126 gave PVO forces significant advantages over its predecessors. It was possible to detect fighters at a distance of 100 km (62 miles) and bombers at a distance of 200-300 km (124-186 miles). At an altitude of 2,000-5,000 m (6,560-16,400 ft) it was possible to detect fighters against background clutter at a distance of 100 km (62 miles) and ships of the cruiser class at 400 km (248 miles). Early warning could be provided at ranges of up to 2,000 km (6,560 miles) from PVO command centres; early warning times could be extended by up to three hours, depending on the distance to the patrol area.

The high cruising speed of the Tu-126 allowed the PVO to change early warning options in response to possible attack scenarios; this was particularly important in consideration of the size of the Soviet Union. Tu-126 transfer times to patrol sites were critical, however, as it could take many hours to get an aircraft on location under certain conditions (for example, redeploying the aircraft from the Kola Peninsula area in the north to the Vladivostok area in the Soviet Far East took 10 hours). Bad weather was not a problem for the Tu-126, as it could fly above or around most inclement weather conditions; radar picket ships at sea did not have this luxury. The Tu-126 could perform its mission in conditions as difficult as those found in the Arctic where land- and ocean-based pickets often were incapacitated by adverse weather conditions.

Overall, it was concluded the Tu-126's most notable attribute was its high dependability under all environmental extremes. Additionally, its electronic countermeasures suite, coupled with its ability to detect adversary aircraft and other potential threats at great distance, was considered an excellent defensive system that made the aircraft difficult to detect and destroy.

The Tu-126 was found to be as effective against surface vessels as it was against air-



Above and below: Two more views of the Tu-126 prototype. Note that the c/n is stencilled on the nose and tail as 618601 for some reason. Note that no IFR probe is fitted (the prototype never received it, IFR tests being conducted on a production example).





Top and above: Stills from a cine film showing an early-production Tu-126 AWACS taking off. Note the IFR probe on the nose and the large ventral fin.



An air-to-air from the same film, showing the dark-coloured flaps, the heat shields aft of the engine jetpipes and the characteristically soot-blackened main landing gear fairings.

borne targets. The great range of its search radar enabled it to operate at great distances from hostile aircraft carrier fleets while monitoring their movements and activities. This stand-off range also reduced the risk of interception by carrier-borne fighters.

Conversely, co-operative intercepts utilising the Tupolev Tu-128S-4 weapons system (comprising the Tu-128 long-range interceptor and its R-4R and R-4T air-to-air missiles) in concert with the Tu-126 were investigated as the latter went into development. This had been instigated by the PVO and, upon detailed study, had led to the conclusion that such a system could extend enemy aircraft interception range to 1,000 km (621 miles) from the Soviet borders. Western bombers, such as the Boeing B-52 Stratofortress and the Avro Vulcan, could be neutralised as a threat if that buffer could be provided routinely by the Tu-126.

To cater for the Tu-126/Tu-128 co-operative intercepts, an intercept officer was introduced into the Tu-126's crew. It thus became possible to integrate the fighter's capabilities with the long-range detection data from the Tu-126. This had not previously been considered an aspect of the Tu-126 mission; once perfected, however, it worked well.

Unfortunately the Tu-126 remained viable as an early warning and control system only until the end of the 1960s. By then NATO strike aircraft had gained the ability to penetrate Soviet airspace at low and ultra-low altitudes. Detecting them at acceptable range was beyond the Tu-126's capabilities. One of the inherent shortcomings in the Liana radar was its very limited 'look-down' capability against low-flying targets, although special training for Tu-126 crews allowed the aircraft to fly at a lower altitude so that its radar could pick such targets out. As a result, development of a new system was initiated, this effort eventually resulting in the Il'yushin/Beriyev A-50 (see Chapter 2). Much more capable than its predecessor, the A-50's Shmel' (Bumblebee) mission avionics suite had special features dramatically improving its ability to track aircraft operating at low altitudes while hiding in background clutter. Work in this direction had begun as early as 1966 at MNIP under General Designer V. P. Ivanov, and work on the Shmel' suite began in earnest in 1969.

Prior to the definitive development of the Shmel' system, the Tupolev bureau began studying airframe options capable of carrying it – including the Tu-126. As the system grew, so did the requirements applied to the aircraft that was to carry it. Among the less obvious concerns was the mission equipment's cooling needs, an issue of considerable importance, considering the many kilowatts of energy that would be consumed powering

the radar. Two large heat exchangers were thus to be installed under the fuselage to meet the heat dissipation requirement.

Regardless of the eventual successes scored by the Tu-126, by the end of the 1960s it had outlived its usefulness and had been overtaken by newer technologies; it was also markedly inferior to the Boeing E-3A Sentry AWACS based on the Boeing 707-300B. Still, there was no other option immediately available; therefore the handful of production Tu-126s soldiered on until 1984 when sufficient numbers of the A-50 were available to replace them. There were no fatal accidents during the Tu-126's service career; however, one aircraft captained by Major Khakamov was struck off charge after suffering permanent structural deformation in a heavy landing at Siauliai. The luckless pilot was demoted.

The Tu-126 in Detail

Type: Long-range airborne early warning and control aircraft. The airframe is of riveted all-metal construction and is largely made of D16T duralumin. The crew complement comprises two flight crews of five and two mission crews of seven working in shifts.

Fuselage: Semi-monocoque stressed-skin structure of beam-and-stringer construction. The cross-section is circular, with a maximum diameter of 4.2 m (13 ft 9½ in); the skin thickness varies from 0.8 mm (0½ in) to 3.5 mm (approx. 0¾ in).

Structurally the fuselage is divided into five sections, with production breaks at frames 26, 72, 99 and 110; all but the rearmost two form a single pressure cabin. Section 1 includes the glazed navigator's station (the glazing frame is manufactured as a one-piece magnesium alloy casting and supports the IFR probe) and the flightdeck. The captain sits on the left and the co-pilot on the right; seated behind them are the radio operator (on the left) and the flight engineer (on the right).

The navigator's station features curved Plexiglas panels and an optically flat triplex glass elliptical lower panel. The flightdeck glazing frame is welded from V-section steel profiles, resting on lateral beams. There are five optically-flat birdproof panes made of triplex glass at the front, two triangular side windows and five eyebrow windows; the side and upper panes are made of Plexiglas. The side windows are sliding direct vision windows which can be used as emergency exits on the ground. A dorsal emergency escape hatch is provided between frames 8 and 10 to be used in the event of ditching.

An unpressurised ventral bay for the radar antenna enclosed by a detachable teardrop-shaped glassfibre radome is located between frames 4 and 7. The nosewheel well is located



This air-to-air of a late-production Tu-126 shows the extended tailcone housing an SPS-141 active jammer.

further aft between frames 8 and 19; it incorporates the crew entry/emergency exit hatch (frames 13-15). A plug-type entry door of quasi-oval shape (the aperture is 'flattened' at the bottom to provide an even threshold) is located on the port side, with a similar service door further forward on the starboard side; they are 'inherited' from the Tu-114. A dorsal teardrop fairing housing star trackers is installed near these doors.

Sections 2 and 3 house the main cabin divided into several bays; a second ventral escape hatch is provided between frames 30 and 32. The first bay accommodates a toilet and the radar intercept operators' consoles along the starboard wall; one of them is the workstation of the radar intercept officer responsible for co-operative intercepts.

Section 2 incorporates the wing centre section between frames 38 and 50. Stainless steel reinforcement plates are riveted to the fuselage sides in the inboard propellers' plane of rotation between frames 31 and 34 to protect the skin against pieces of ice separating from the propeller blades. A second entry door, left over from the Tu-114, is located on the port side of section 3. All doors are provided with rain gutters. The tapering aft portion of section 3 carries the fin fillet. Frame 99 is the rear pressure dome.

The unpressurised Section 4 incorporates attachment points for the fin, the ventral fin and stabiliser carry-through structure. Section 5 is a tailcone. On the prototype (c/n 61M601) and three production aircraft (c/ns 65M611, 65M613 and 66M621) the tailcone is identical in shape to that of the Tu-114 and houses chaff dispensers; on the other five Tu-126s it is an elongated ECM fairing housing an active jammer.

A vertical pylon of symmetrical airfoil section and trapezoidal shape is mounted at the junction of fuselage sections 2 and 3; it is 2.6 m (8 ft 6¾ in) tall and carries a

rotodome of 11 m (36 ft 1 in) diameter and 2 m (6 ft 6¾ in) depth. The greater part of the rotodome is a metal support structure with 20 truss-type ribs, 27 stringers, skin panels and a leading-edge section featuring a curved spar, webs and skin panels; it incorporates a bearing of 1,200 mm (3 ft 3¾ in) diameter, a hydraulic drive unit and maintenance hatches. The dielectric portion comprises six truss-type ribs, a web, a curved leading-edge beam and skin panels. The pylon is built in three portions (leading-edge section, centre section and trailing-edge section) and features seven ribs. The centre section incorporates a vertical tunnel for the antenna waveguides and power cables (which also provides maintenance access to the rotodome) and features vortex generators to improve efficiency of the controls.

Wings: Cantilever low-wing monoplane of basically trapezoidal planform; trailing edge broken by main landing gear fairings. Sweep-back at quarter-chord 35°, anhedral from roots. The wings utilise TsAGI high-speed airfoils.

The wings are two-spar, stressed-skin structures with trailing-edge sections riveted to the rear spar. Structurally they are built in five pieces: the centre section, inner wings (ribs 2A-25) and outer wings (ribs 25A-41), plus tip fairings; the sections are joined by flanges. Ribs 1, 9, 15 and 25 on each side are sealed; ribs 7-9, 10, 12, 14, 16, 18, 20, 22 and 24 are reinforced, serving as attachment points for the flaps, ailerons, spoilers and main gear fairings. The ribs are at right angles to the rear spar, except for the centre section ribs and ribs 2/2A, which are parallel to the fuselage axis. The wing torsion box houses bladder-type fuel tanks.

The centre section is integral with the fuselage, the spars being attached to mainframes 38 and 50. The flat upper skin forms



Above: This view of a late-production Tu-126 taken from a shadowing US Navy McDonnell F-4J Phantom II shows clearly the ELINT blisters on the rear fuselage. The lateral blister and panel are for the SRS-6 and SRS-7 sets respectively, while the ventral pair of blisters is for the SRS-4 set.



This view shows the cigar-shaped fairings at the stabiliser tips associated with the Arfa data link system.



Above: Another magnificent shot of a 'long-tail' Tu-126 cruising over thick overcast shows the aircraft's sleek lines that even the huge rotodome cannot spoil to a major degree.



This aspect of the same aircraft illustrates very well that less than half of the Tu-126's rotodome is dielectric. Note also the kinked wing trailing edge.

the pressure floor; the three-piece lower skin is attached by screws. The wing/fuselage joint is covered by a fairing.

The inner wings carry the engine nacelles. The inboard engine nacelles continue aft to blend into large pointed main landing gear fairings projecting beyond the wing trailing edge; the fairings have a basically rectangular cross-section changing to circular at the tips. Each inner wing has two prominent boundary layer fences designed to delay tip stall; they are built in several portions to avoid deformation as the wings flex. The inner wings are equipped with two-section slotted flaps located inboard and outboard of the inner engines; the wing chord is increased in this area so that the trailing edge features a double kink. Each flap section moves on three curved tracks housed inside the wings and is actuated by twin screw jacks driven by electric motors via drive shafts and angle drives. Flap settings are 25° for take-off and 35° for landing. Stainless steel heat shields are provided on the underside to protect the wing skin against the hot engine exhaust, extending across the flaps to the trailing edge.

The outer wings each have one boundary layer fence. The outer wing trailing edge is occupied by three-section ailerons, each section being actuated independently; the inboard sections feature servo tabs.

The multi-section leading edge is detachable, doubling as a de-icer. There are no leading-edge devices.

Tail Unit: Conventional swept tail surfaces of all-metal stressed-skin construction. The *vertical tail* consists of a fin with a prominent fillet and a one-piece rudder featuring a large trim tab. The fin is a two-spar structure with a detachable leading edge doubling as a de-icer; there are five rudder mounting brackets and a lower rudder mounting post. The fin is augmented by a large ventral strake.

The variable-incidence *horizontal tail* comprises a centre section housed inside the rear fuselage, two stabilisers and one-piece elevators with trim tabs. Each stabiliser is of similar two-spar construction with five elevator mounting brackets. Cigar-shaped antenna fairings are mounted at the tips.

Landing Gear: Retractable tricycle type; all three units retract aft. All three units have oleo-pneumatic shock absorbers.

The hydraulically-actuated nose unit has jury struts and an aft-mounted breaker strut. It is fitted with twin 1,100 x 330 mm (43.3 x 12.99 in) K-279 non-braking wheels. The nose unit has a steering mechanism/shimmy damper and is controlled by the rudder pedals. In an emergency the nose gear unit can be extended pneumatically, allowing the flight crew to bail out through the nosewheel well.

The main units are attached to the inner wing ribs 11-13 and actuated electromechanically, with emergency extension by means of a manually driven windlass. Each unit has a forward-mounted telescopic retraction strut and a four-wheel bogie equipped with 1,500 x 500 mm (59.0 x 19.68 in) KT-25 brake-equipped wheels. When extended, the main gear struts are inclined slightly forward. In no-load condition the bogies assume a slightly nose-down attitude; during retraction they are rotated aft through 180° to lie inverted in the abovementioned fairings.

The nosewheel well is closed by two pairs of doors which remain open when the gear is down. Each main unit has two large main doors, two small clamshell doors in line with the gear fulcrum (mechanically linked to the strut) and a narrow curved strip attached to the retraction strut. The main doors are hydraulically actuated, opening only when the gear is in transit.

Powerplant: Four Kuznetsov NK-12MV turboprops having a 15,000-ehp take-off rating and an 8,080-ehp cruise rating at 10,000 m (32,810 ft). The engine was manufactured by the Kuibyshev Engine Factory named after Mikhail V. Frunze (now Motorostroitel JSC).

The NK-12MV is a single-shaft turboprop with an annular air intake with inner and outer cones connected by six radial struts, a 14-stage axial compressor, an annular combustion chamber, a five-stage uncooled axial turbine and a fixed-area jetpipe. Power is transmitted via a single-stage differential gearbox with oil cooling which also serves as the accessory gearbox. The NK-12MV is started by a TS-12MA jet fuel starter on the left side of the engine casing – a small gas turbine engine driving the spool via a clutch (TS = *toorbostartyor* – turbine starter). The NK-12 is the world's first turboprop engine to feature air bleed valves in the compressor section, cast turbine blades, turbine blade gap control and an integrated fuel control unit.

Engine pressure ratio 9.3 at take-off power and 13.0 at cruise power; mass flow at take-off power 55.8 kg/sec (123 lb/sec); turbine temperature 1,150°K. Specific fuel consumption (SFC) 0.21 kg/hp-hr (0.46 lb/hp-hr) at take-off power and 0.158 kg/hp-hr (0.34 lb/hp-hr) at cruise power. Length overall 6,000 mm (19 ft 8 1/4 in), maximum diameter 1,150 mm (3 ft 9 1/4 in); dry weight 3,065 kg (6,760 lb) less propellers. The NK-12MV has a 4,500-hour service life.

The engines are mounted in individual nacelles attached to the inner wing sections and carried in truss-type bearers; the engine attachment lugs are mounted on the forward and centre casings. Each nacelle consists of a one-piece annular forward fairing, hinged cowling panels and a fixed rear fairing incor-

porating a bifurcated jetpipe. The ventral oil cooler (with air intake and rear airflow adjustment flap) is detachable.

The engines drive Stoopino Machinery Design Bureau AV-60K eight-blade contra-rotating reversible-pitch automatically feathering propellers with spinners. Diameter 5.6 m (18 ft 4 1/2 in), weight 1,190 kg (2,620 lb); speed at take-off power 730 rpm, thrust at take-off power 14,800 kgp (32,630 lbst). The AV-90 has four blades in each row; the front row rotates anti-clockwise and the rear propeller clockwise when seen from the front.

Control System: Conventional mechanical dual control system with push-pull rods, control cranks and levers. The control rods and cables are provided with bronze/rubber pressure seals where they exit the pressure cabin. All control surfaces have both aerodynamic and mass balancing. Gust locks are provided to prevent damage to the system by high winds while the aircraft is parked.

Directional control is provided by a one-piece rudder of single-spar construction provided with a GU-84 reversible hydraulic actuator (*ghidro 'usilitel'* – hydraulic booster). The rudder features a trim tab hinged on four brackets; this has aerodynamic and mass balancing and is powered by an MP-100A-36 electric drive.

Pitch control is provided by one-piece manual elevators. Each elevator incorporates a trim tab controlled electrically (by a UT-11 or UT-11M drive) or manually by means of cables and handwheels. To enhance pitch control at low speed and provide longitudinal trim the Tu-126 features variable-incidence stabilisers adjusted by an electric drive.

Roll control is provided by three-section ailerons on the outer wings powered by GU-85 reversible hydraulic actuators. The inner sections incorporate trim tabs with MP-100MT-81 electric drives.

The control system includes an AP-15 autopilot.

Fuel System: The fuel system comprises 68 non-self-sealing bag-type tanks in the wing torsion box. They are split into four groups, one for each engine, and connected via cross-feed valves. An SETS-320A fuel metering system measures the amount of fuel in each group of tanks. Fuel grades used are Soviet T-1, TS-2, T-2 or RT kerosene and their mixtures.

The Tu-126 has single-point pressure refuelling. As part of this, an emergency fuel jettison system and a fuel tank venting system are provided. An in-flight refuelling probe is located ahead of the flightdeck glazing and is connected to the main tanks by a fuel transfer line which runs along the starboard side of the fuselage.

Electrics: Two electric subsystems are provided. Main 28.5 V DC power supplied by eight 18-kilowatt engine-driven GSR-18000 generators (two on each engine). Backup DC power provided by two 12SAM-55 lead-acid batteries (55 A-h) and two ATG-18000F generators driven by a ram air turbine (*avareynny toorboghenerahotor*). All DC power sources are connected in parallel.

208 V and 115 V/400 Hz single-phase AC supplied by four engine-driven SGO-30URS variable-frequency alternators. 36 V/400 Hz stable-frequency three-phase AC for the radars, autopilot, navigation systems and flight instruments supplied by two (main and backup) 1.5-kVA PT-1500Ts AC converters (*preobrazovahel' tryokhfahznyy*).

DC power is distributed via seven distribution panels and circuit breaker panels in the flightdeck and galley. The central distribution panel is located in the rear baggage compartment on the port side of frame 48; the fuse box is located at frame 15 in the No.1 equipment bay. Two ground power receptacles (ShRAP-500 for DC power and ShRAP-200 for AC power) are provided on the fuselage underside between frames 48 and 49.

Hydraulics: Three separate hydraulic systems, two of which (main and emergency) have a nominal pressure of 150 kg/cm² (2,135 psi) and are called high-pressure systems; the third system has a nominal pressure of 75 kg/cm² (1,071 psi).

The main system operates the nose landing gear retraction mechanism, nosewheel steering mechanism, wheel brakes (in normal mode) and windshield wipers. The emergency system serves for emergency wheel braking. Hydraulic pressure in both systems is provided by an electric pump and an NR-01 hand-driven emergency pump; there is a common hydraulic tank and one hydraulic accumulator in each high-pressure system.

The low-pressure system operates the rudder and aileron actuators; hydraulic pressure is provided by two pumps on the inboard engines.

Pneumatic System: The pneumatic system is responsible for emergency nose gear extension, fuel jettisoning, emergency propeller feathering and de-icing system actuation. Compressed air is supplied by AK-150MK compressors mounted on the inboard engines (using engine bleed air from the 11th compressor stages). It is stored in hollow main gear jury struts doubling as air bottles charged to 155 kg/cm² (2,214 psi) and an air bottles charged to 60 kg/cm² (857 psi).

Fire Suppression System: Six fire extinguisher bottles charged with carbon dioxide (CO₂) for fighting fires in the engine nacelles

and in the wing centre section torsion box. The system has a three-stage operating algorithm; the first shot is triggered automatically by flame sensors of the three independent SSP-2A fire warning systems (*sistema signalizahtsii pozhara*), the second and third shots are fired manually at the discretion of the crew.

Two separate systems (port and starboard) featuring two bottles and a two-stage operating algorithm are provided for fighting fires inside the engines proper. Additionally, OU-2 portable CO₂ fire extinguishers are provided in the cabin and flightdeck.

De-icing System: The engine air intakes, oil coolers and inlet guide vanes are de-iced by hot air bled from the 14th compressor stage. The propeller blades and spinners, as well as the flightdeck/navigator's station glazing have electric (115 V AC) de-icing; the heated panes are provided with an AOS-81M automatic temperature regulator to prevent cracking. 28.5 V DC electric de-icing on the wing and tail unit leading edges, pitot heads and static ports. A radioactive-isotope icing detector is installed on the port side of the nose.

Air Conditioning & Pressurisation System: The entire fuselage between frames 1 and 94 is pressurised by air bled from the 9th compressor stage. The pressurisation system automatically maintains sea level pressure up to 5,000 m (16,400 ft); a pressure differential of 0.5 kg/cm² (7.14 psi) is maintained at higher altitudes. The engine bleed air is fed first into an air/air heat exchanger located in a fairing below the wing leading edge and then into a cooling turbine; the cabin temperature is maintained at around 20°C (68°F). In the flightdeck, air is directed at the glazing to stop it from misting up.

Avionics and Equipment: The Tu-126 is fully equipped for poor-weather day/night operation, including automatic flight assisted by an autopilot.

Navigation and piloting equipment: The aircraft has an AP-15 autopilot, a Put'-1 (Way) semi-automatic navigation system, a long-range radio navigation (LORAN) system with a 'towel rail' aerial on the forward fuselage, offset to port and an RSBN-2S Svod/Vstrecha (Dome/Rendezvous) short-range radio navigation system (*rahdiotekhnicheskaya sistema blizhney navigahtsii*) with two flush antennas built into the fin on each side. Navigation is aided by a DISS-M *Molniya* (Lightning) or DISS-1 Doppler speed/drift sensor system (*doplerovskiy izmeritel' skorosti i snosa*), twin BTs-63 star trackers for celestial navigation in a dorsal fairing on the forward fuselage and an R-1 Rubin-1Sh (Ruby; pronounced *roobin*) panoramic navigation/bomb-aiming radar in a chin radome.

The navigation/piloting equipment further includes main and backup ARK-11 and ARK-U2 automatic direction finders (*avtomaticheskii rahdiokompas* – ADF), each with a loop aerial and a strake aerial, a GPK-52 gyro compass (*gheeropolukompas*) and an RV-4 (RV-UM) radio altimeter (*rahdiovyotomer*) with dipole aerials.

Instrumentation includes AGD-1S artificial horizons, KUS-1200 combined airspeed indicators (*kombineerovanny ooka-zahtel' skorosti*), a VD-20 two-needle barometric altimeter (*vysotomer dvookhstrelochnyy*), a UUT pitch angle indicator (*ookazah-tel' oogla tangazha*), EUP-53K turn and bank indicators (*elektricheskii ookazahtel' povo-rota*), Model 13-20ChP chronometers, VAR-30M vertical speed indicators (*variometr*), SSN-1 dynamic pressure indicators (*signalizahtor skorosnovo napora*), an MS-1 Mach meter, a DAK-FB-5 remote celestial compass, an AK-53 celestial compass and an SP-1M periscopic sextant at the navigator's station.

Communications equipment: For long-range air/ground communications the Tu-126 has 1-RSB-70 or R-807 HF communications/command link radios with a wire aerial running from the forward fuselage to the rotodome pylon. Later aircraft have a Mikron HF radio with a forward-pointing probe aerial on the fin top fairing. Short-range air/air and air/ground communications are catered for by US-8, RPS, R-813 and R-836 Neon radios.

The communications equipment further includes an SPU-7 intercom (*samolyotnoye peregovornoye oostroystvo*) and an SGU-16 public address system (*samolyotnoye gromkogovoryashcheye oostroystvo*).

Mission avionics: Liana 360° search radar in the rotodome, with operators' consoles in the cabin; a cooling system is provided with a heat exchanger under the rear fuselage. Production aircraft have an SRS-6 Romb-4A automatic ELINT system (Rhombus; SRS = *stahntsiya razvedki svyazi* – communications intelligence set) with lateral antenna blisters on the rear fuselage, an SRS-7 Romb-4V ELINT system lateral flush antennas further aft and an SRS-4 *Kvadraht* (Square) signals intelligence (SIGINT) system with tandem ventral teardrop fairings. An Arfa data link system with antenna fairings at the tips of the horizontal tail is provided.

ECM equipment: Tu-126s c/ns 61M601, 65M611, 66M613 and 66M621 have ASO-2B-126 chaff dispensers in the tailcone. The remaining examples featured an extended ogival tailcone housing an SPS-100 Rezeda active jammer.

IFF system: SRO-2M Khrom (Chromium; NATO *Odd Rods*) IFF transponder (*izdeliye 023*) with characteristic triple rod aerials on top of the flightdeck glazing and under the ventral fin.

Rescue/Survival Equipment: PSN-6A life rafts (*plot spasahtel'nyy nadoovnoy*) are provided for the crew in case of ditching. For overwater missions the crew is issued with VMSK heat-insulated waterproof suits.

Tu-126LL Avionics Testbed (*izdeliye* LL 'A' and LL '2A')

In 1969 the Soviet Council of Ministers issued a directive initiating development of a mission avionics suite for a new-generation AWACS. The aircraft itself, designated A-50 or *izdeliye* A, was to be developed by the Taganrog Machinery Plant named after Gheorgiy M. Beriye (then headed by A. K. Konstantinov) pursuant to a joint Council of Ministers/Communist Party Central Committee directive issued in 1973. The system was to have an enhanced 'look-down' capability enabling the A-50 to detect low-flying targets.

As part of the effort to create the A-50, its mission avionics had to be flight-tested. To this end the CofM Presidium's Commission on defence industry matters (VPK – *Voyenno-promyshlennaya komissiya*) adopted a special ruling on 25th August 1975 requiring a single Tu-126 to be converted into an avionics testbed called Tu-126LL or LL 'A'. LL means *letayuschaya laboratoriya* – literally 'flying laboratory' (this Russian term is used indiscriminately for any kind of testbed or research/survey aircraft), while the 'A' refers to *izdeliye* A.

Accordingly the Tu-126 prototype, which had been delivered to 67th IAEWS at Siauliai upon completion of the trials, was withdrawn

and ferried to Taganrog for conversion. This involved removal of the original rotodome and all other elements of the old Liana suite, as well as of the *Kristall-L* data link system, the equipment in the relief crew rest area, the PSN-6A life rafts and the ASO-2B-126 chaff dispensers. Instead, a new RA-L mission avionics suite was fitted (L stood for *laboratornyy obrazets* – 'laboratory [that is, development] example') comprising a new RA-10 rotodome, avionics cooling systems (including a liquid cooling system for the search radar's antenna array in a fairing under the rear fuselage), a power supply system and a test and data recording equipment suite. The power supply system included a special TG-60/2S turbine-powered generator driven by engine bleed air and installed in a dorsal fairing above the wing leading edge. The internal layout of the Nos 2 and 3 cabin bays was changed appreciably; these featured new equipment racks and crew workstations and two extra bunks. The crew complement was increased to 13 (five flight crew, seven mission equipment operators for the RA-L suite and a test equipment operator).

The new rotodome was both larger and almost 4,000 kg (8,820 lb) heavier than the original one. Hence limits had to be imposed on the testbed's maximum take-off weight, top speed and G loads. Unlike the original design, the new rotodome had front and rear dielectric portions of identical size, only the narrow centre portion being made of metal.

Manufacturer's flight tests of the LL 'A' testbed lasted from 1st August to 21st Octo-

ber 1977. During this time the RA-L suite's power supply and cooling systems were tested and the structural strength and vibration characteristics of the new rotodome were verified. The actual first flight took place on 15th August with V. P. Dem'yanovskiy in the captain's seat; V. V. Toolyakov was the engineer in charge. At this stage the aircraft logged a total of 27 hours 39 minutes in nine test flights; the crews noted that the new rotodome had virtually no effect on the machine's handling.

When the Il'yushin and Beriye bureaus started work on the upgraded A-50M AWACS (*izdeliye* 2A) equipped with the Shmel'-2 mission avionics suite, the Tu-126LL testbed was modified accordingly and designated LL '2A'. This configuration featured massive cylindrical equipment pods at the wingtips. Their front and rear portions were dielectric, enclosing flat-plate antennas. The modified aircraft arrived at Lookhovitsy-Tret'yakovo on 13th March 1987. However, in 1990 all further work on this programme was terminated. The Tu-126LL was flown to Zhukovskiy and struck off charge, and the stripped-out hulk sat on the local dump at least until August 1995, whereupon it was finally broken up – sadly, as at least one example of the Tu-126 should have been preserved for posterity.

The following description outlines the basic changes introduced on the Tu-126LL.

The crew comprises 13 persons: the usual flight crew of five, a test equipment operator and seven mission equipment operators (chief technician, technician, back-up



The Tu-126LL avionics testbed (alias LL 'A') takes off, leaving a pall of snow behind. The additional ventral heat exchanger housing instead of the ventral ECM blisters is obvious, but the new RA-10 rotodome is not. Note also the extra dorsal blister housing the TG-60/2S turbine generator.



The stripped-out hulk of the Tu-126 (LL '2A') on the dump at Zhukovskiy. The cylindrical pod at the starboard wingtip is not visible here.

technician, data processing operator, data registering operator, data recording operator and maintenance engineer). The radar intercept operators' consoles of the deleted Liana suite in Bay 1 are used as back-up equipment; the former radar intercept officer's workstation is converted into the test equipment operator's station. Bay 2 accommodates the maintenance engineer's workstation, a rest area for two, an avionics rack and a spares box on the right; located opposite are the data-registering operator's console, two more avionics racks and a second spares box. A dorsal fairing located above this bay between frames 40-48 houses the TG-60/2S turbine generator.

Bay 3 seats the chief technician, technician and back-up technician on the right and the data-processing operator with his equipment rack on the left.

Bay 4 is entirely occupied by the modules of the RA-L suite being tested; so is Bay 5, which houses the transceiver units. To reduce the harmful effect of the electromagnetic pulses generated by the equipment, Bays 4 and 5 are separated by a solid metal bulkhead; for the same purpose the navigator's station, flightdeck and cabin windows are all provided with a wire mesh and gold plating to keep the radiation out.

Unlike standard Tu-126s, which have AV-60K propellers, the Tu-126LL is fitted with AV-60N propellers of an identical diameter (5.6 m) for unknown reasons.

As noted earlier, the RA-10 rotodome of the RA-L system features two identical dielectric portions attached to a narrow metal centre segment; diameter is 10.2 m (33 ft 5³/₈ in). The dielectric portions have a honeycomb construction and feature metal attachment

rims. At 6 rpm, the RA-10 rotates slower than the standard rotodome of the Tu-126.

To ensure proper operating conditions for the mission equipment, which generates a lot of heat, the Tu-126LL is fitted with several equipment cooling systems operated by the technician. These include a closed-circuit air cooling system with an air/air heat exchanger;

several direct air cooling systems utilising cabin air; and two liquid cooling systems catering for the modules which are installed between frames 71 and 80. The air/air heat exchanger and the water radiator which form part of the cooling system are installed in a ventral fairing beneath Bay 5 (that is, frames 77 to 83).

Tu-126 Specifications

	Tu-126	Tu-126LL
Length overall:		
without rear ECM fairing and less IFR probe	55.0 m (180 ft 5 ¹ / ₂ in)	55.0 m (180 ft 5 ¹ / ₂ in)
with rear ECM fairing and IFR probe	57.9 m (180 ft 11 ³ / ₈ in)	-
Wing span	51.4 m (168 ft 7 ⁷ / ₈ in)	n.a.
Height on ground	15.5 m (50 ft 10 ¹ / ₂ in)	15.5 m (50 ft 10 ¹ / ₂ in)
Wing area, m ² (sq ft)	311.1 (3,348.4)	311.1 (3,348.4)
Take-off weight, kg (lb):		
normal	155,172 (342,090)	n.a.
maximum	171,000 (376,990)	172,000 (379,190)
Maximum landing weight, kg (lb)	n.a.	135,000 (297,620)
Maximum fuel load, kg (lb)	n.a.	59,800 (131,830)
Maximum speed at 9,000 m (22,965 ft)		
with a 133,000-kg (293,210-lb)		
all-up weight, km/h (mph)	790 (491)	720 (447)
Cruising speed, km/h (mph)	650-700 (404-435)	690-710 (428-440)
Landing speed, km/h (mph)	n.a.	270 (167)
Service ceiling with a 133,000-kg AUW, m (ft)	10,700 (35,100)	10,400 (34,120)
Range, km (miles):		
on internal fuel	7,000 (4,347)	n.a.
with one in-flight refuelling	10,000 (6,212)	n.a.
Endurance, hours:		
on internal fuel	10.2	n.a.
with one in-flight refuelling	18	n.a.
Take-off run with a 166,000-kg (365,960-lb) take-off weight, m (ft)	2,400 (7,870)	2,700 (8,860)
Landing run, m (ft)	1,200 (3,940)	1,600-1,800 (5,250-5,900)



Two views of a model of the projected 'Soviet Sentry' – the Tu-156. Note the three four-wheel main gear bogies and the remote-controlled tail gun barbette.

Tu-156 ('156') AWACS Aircraft (Project, first use of designation)

As already mentioned, the Tupolev OKB became aware of the Tu-126's obsolescence at an early stage and began work in the second half of the 1960s on a new AWACS capable of countering low-flying targets. This was to incorporate the new Shmel' surveillance radar with a rotodome as used on the Tu-126. In 1969 a government directive was passed ordering the start of work on the Shmel' system, with the PVO proviso that it should be based on an aircraft already in production.

The Tupolev OKB started work on its new-generation AWACS project (tentatively designated '156') in 1970, contemplating several of its existing designs – the Tu-142M, the Tu-154 and the Tu-126 – as possible bases. The Tu-142M was turned down on account of the difficulty in fitting the radar to its relatively narrow fuselage offering limited internal space, although VVS insisted that this aircraft be used – repeating the history of the Tu-95 as a

basis for the Tu-126. The rear-engine, T-tail Tu-154 was also rejected due to adaptation problems (in particular, the rotodome and its wake vortex could cause control problems and create the risk of engine surge) and the aircraft's comparatively limited endurance. The Tu-126 proved the most suitable, but as production had already ended and all the jigs had been thrown away this was a somewhat academic choice.

Analysis of the requirements associated with the Shmel' radar indicated an all-new design would be best, and subsequently the '156' (Tu-156) project crystallised as an aircraft strongly resembling the Boeing E-3A Sentry AWACS. The low-wing aircraft with moderately swept wings and conventional tail surfaces was to be powered by four 12,000-kgp (26,455-lb) Solov'yov D-30KP turbofans carried under the wings in individual nacelles. The rotodome was to be mounted conventionally above the fuselage on twin pylons. But this proved unacceptable to the

Air Force, which insisted that an aircraft already in production should be used; eventually the VVS opted for the Il'yushin IL-76 transport as the basis for the new AWACS. The designation Tu-156 was later re-used for a projected derivative of the Tu-154 using cryogenic fuels.

Tu-156 specifications (project data)

Length	52.5 m (172 ft 2 ³ / ₄ in)
Wing span	45.8 m (150 ft 3 ¹ / ₂ in)
Height on ground	14.6 m (47 ft 10 ¹ / ₈ in)
Fuselage diameter	3.8 m (12 ft 5 ³ / ₈ in)
Wing area, m ² (sq ft)	307 (3,300)
Maximum TOW, kg (lb)	182,000 (401,230)
Weight empty, kg (lb)	107,350 (236,660)
Cruising speed, km/h (mph)	720 (447)
Service ceiling, m (ft)	10,000 (32,810)
Service range, km (miles):	
on internal fuel	5,200 (3,230)
with one in-flight refuelling	6,800 (4,223)
Crew	9

Mainstay: A Joint Effort

Il'yushin/Beriyeв A-50 AWACS Aircraft (IL-76A, *Izdeliye A*)

As noted in the preceding chapter, the Soviet military recognised the need to develop a successor to the Tu-126 AWACS when the aircraft had barely entered production and service. A new-generation AWACS had to be ready for service with the PVO by the time the Tu-126 had gathered moss (oops...), as it would have by the early 1980s. Besides, soon after the Tu-126's service entry the US Air Force fielded its own AWACS – the Boeing E-3A Sentry, which was superior to the Moss on all counts. Therefore, as mentioned earlier, in 1969 the Soviet Council of Ministers initiated development of a successor to the Liana mission avionics suite that would be capable of detecting and tracking low-flying targets, including cruise missiles.

The Tupolev OKB's endeavour to develop an aircraft that would carry the new airborne early warning and control suite is described in Chapter 1. In the meantime, however, other Soviet aircraft design bureaux, including OKB-240 headed by Sergey Vladimirovich Il'yushin, were also trying to develop suitable AWACS platforms. On 7th August 1969 the VPK issued a ruling requiring the Il'yushin OKB to undertake preliminary development of an AWACS designated IL-70. This aircraft, the second project to bear the IL-70 designation (it had been used in 1961 for a 24-seat twin-turbojet regional airliner whose development was discontinued in 1963), was a derivative of the as-yet-unflown IL-76 four-turbofan transport (NATO codename *Candid*).

Presently the IL-76 prototype made its first flight on 25th March 1971, and after two years of extensive testing the type entered production at aircraft factory No.84 in Tashkent. With its high speed, payload and range the IL-76 looked set to be an excellent AWACS platform. Now, as the reader remembers, a key requirement applied to the future AWACS was that it should be based on an aircraft already in production. The Tu-156, however, did not even exist in prototype form. Therefore, the choice of the IL-76 as the second-generation AWACS platform came as no surprise. True, an airliner-type platform like the E-3 – or the stillborn Tu-156 – would have higher flight performance. However, the IL-76 offered ample space for the mission avionics and mission crew (no small thing, since Soviet avionics were typically bulkier than their West-

ern counterparts) while having the ability to operate from semi-prepared runways, which might be a requirement in times of war. Besides, the IL-76 was already entering service with the Soviet Air Force on a mass scale and had built up quite a good reliability record, which meant there would be fewer operational problems with its special-mission derivative. Thus, in 1973 the Communist Party Central Committee and the Council of Ministers issued a joint directive specifying the IL-76 as the basis for the new AWACS.

Following the example of its competitor, the Il'yushin OKB teamed up with the Moscow Research Institute of Instrument Engineering (MNIIP, aka NPO Vega-M) and the Beriyeв OKB (now known as TANTK Beriyeв, *Taganrogskiy aviatsionnyy naoochno-tekhnicheskii kompleks imeni Gheorgiya Mikhailovicha Bereeyeva* – the Taganrog Aviation Scientific & Technical Complex named after Gheorgiy M. Beriyeв) to create an AWACS derivative of the IL-76M military transport.

The resulting aircraft was designated A-50 or *izdeliye A*. The 'non-Il'yushin' designation is due to the fact that the Beriyeв OKB performed the mission avionics integration effort; cf. the Beriyeв A-40 Albatross anti-submarine warfare amphibian. Had Il'yushin alone been responsible for the job, the designation would have been something like IL-76RLD (*rahdi-*

olokatsionnyy dozor – radar picket) – or IL-70. Hence, Western aviation experts have tended to attribute the A-50 solely to the Beriyeв OKB – although, in fairness, the Il'yushin OKB should be listed as a 'co-author'.

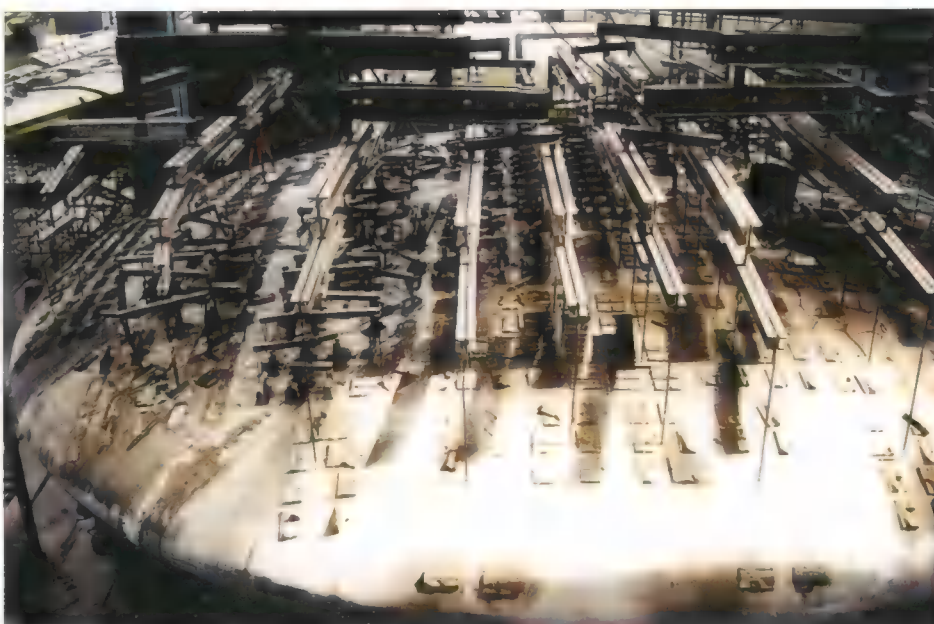
The A-50 is equipped with the Shmel' (Bumblebee) mission avionics suite built around a coherent pulse-Doppler 360° surveillance radar of the same name. The radar can track up to 50 targets at a time with a maximum range of 230 km (142 miles); large targets like surface ships can be detected and tracked at up to 400 km (248 miles). The suite also includes an active IFF system, a data processing and presentation system, data storage equipment and secure digital communications/data link equipment for communicating with ground and shipboard command, control, communications and intelligence (C³I) centres and friendly fighters.

General Designer V. P. Ivanov headed the development effort at MNIIP. At the Beriyeв OKB, Chief Designer A. K. Konstantinov exercised overall control of the integration and debugging effort, his deputy S. A. Atayants being appointed the A-50's project chief.

The main structural change as compared to the IL-76M was the conventionally-located 'saucer' rotodome housing the RA-10 antenna as tested on the Tu-126LL. Mounted on two tapered pylons immediately aft of the



As this photo of one of the RA-10 rotodome's dielectric shells shows, the A-50's rotodome is deep enough to stand in it even when wearing a top hat.



The photos on this page show the RA-10 rotodome undergoing static tests at the Beriyev OKB's experimental shop in Taganrog.

wings, the rotodome had a diameter of 10.8 m (35 ft 5 $\frac{1}{2}$ in) and was some 2 m (6 ft 6 $\frac{3}{4}$ in) deep. The rotodome was located more than one diameter ahead of and well below the horizontal tail. The lift generated by the rotodome increases the downwash on the stabilisers, reducing their efficiency, but the rotodome itself contributes a stabilising influence. Also, wake turbulence from the rotodome reduces the efficiency of the vertical tail but the rotodome pylons make up for this – albeit at the expense of reduced lateral stability because of the additional sideforce above the CG.

The need to accommodate the mission equipment led to a few other airframe changes. The extensive glazing of the navigator's station was replaced by a large curved dielectric panel, leaving only a single small window on each side. These windows and the two rearmost flightdeck windows on each side had gold plating to protect the crew from the electromagnetic pulses generated by the radar. The said dielectric panel featured four tooth-like projections at the bottom, making the aircraft look like a pleased rodent. The weather radar's radome was slightly smaller and has a reshaped joint line with the fuselage, with two small dielectric panels on either side aft of it.

The IL-76 has two entry doors that can be used for parachuting personnel; on the A-50, however, the port side door was deleted as superfluous. So was the tail gunner's station of the *Candid-B* military variant on which the A-50 is based; it gave way to an avionics bay with two aft-facing antennas covered by large fairings where the UKU-9K-502 tail barrette and the glazing used to be. A large cooling air intake was added at the base of the fin. The three-segment cargo doors were deleted; the cargo ramp remained but was non-functional.

The main landing gear fairings were modified considerably to house some of the equipment. Instead of tapering off at both ends as on the IL-76, they had a constant cross-section almost throughout; the blunt forward portions incorporated two circular air intakes of unequal size. The TA-6 auxiliary power unit was relocated from the front portion of the port fairing to its rear end, the lateral intake door and exhaust giving place to a dorsal 'elephant's ear' intake and a downward-angled exhaust.

The A-50 bristled with various antennas. Four ECM antennas in large teardrop fairings were located on the forward and aft fuselage sides to provide full 360° coverage; a large dielectric fairing ahead of the wing torsion box housed satellite communications (SATCOM) and navigation antennas. Numerous blade aerials were located dorsally and ventrally on the forward fuselage and ahead of the cargo



Above: The third prototype A-50, ■ converted IL-76 (c/n 0013430875, f/n 2209). The tactical code '20 Red' is obscured by the engines. This view shows the characteristic front end, the SATCOM fairing ahead of the wings, the modified main gear fairings and the initial lack of horizontal strakes on their all portions.



The first prototype A-50 converted from IL-76M CCCP-76641 (c/n 073409243, f/n 0701). Again, the horizontal strakes have yet to be fitted. Note the unusual all-white nose ahead of the nose glazing.



Above: A front view of the first prototype ('10 Red'), showing the large cooling air intakes in the main gear fairings and the forward ECM antenna blisters. Below: Three-quarters rear view of '10 Red', showing the rear avionics bay supplanting the tail gunner's station and the aft position of the APU.





Above: A rear view of '10 Red', showing the rear ECM and ESM antennas.

Below: This side view illustrates the position of the rotodome with respect to the tail, as well as the cooling air intake at the base of the fin.





Top: A-50 '20 Red' taxiing at Taganrog.

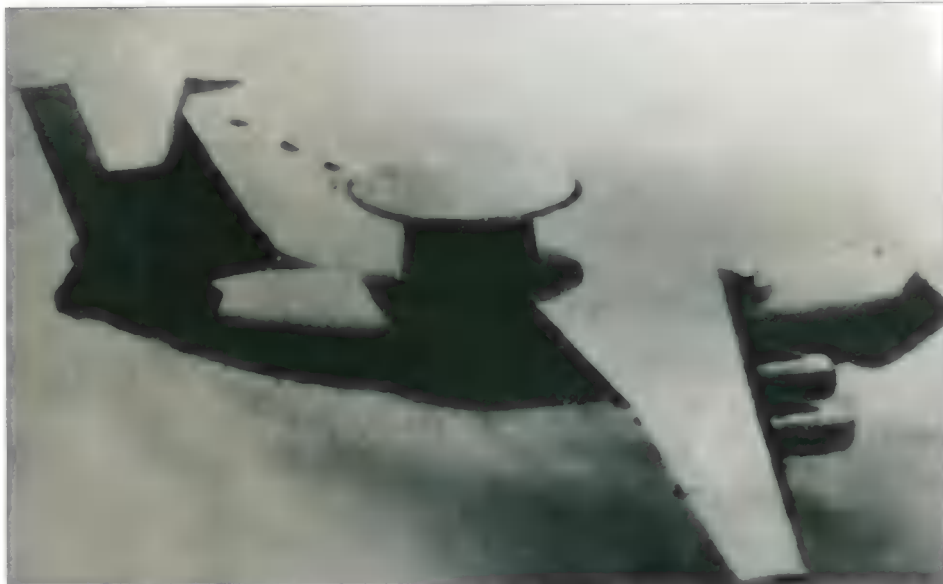
Above: A typical production A-50 (note the different colour of the nose radomes and the larger anti-glare panel on the nose).

ramp, and two large strake arials were fitted aft of the nose gear. Chaff/flare dispensers were incorporated into the rear fuselage flush with the skin.

Like its predecessor (the Tu-126), the A-50 was provided with a telescopic IFR probe located ahead of the flightdeck glazing, with an external fuel conduit running along the starboard side above the entry door to the wings. For night refuelling the probe was illuminated by retractable lights, a standard feature on Soviet heavy aircraft using the probe-and-drogue system.

The fully pressurised cargo hold was converted into a mission crew cabin and an avionics bay. The crew consisted of fifteen persons: two pilots, a flight engineer, a navigator, a radio operator and ten mission equipment operators – radar intercept officers (RIOs), ECM operators and communications officers.

When designing the A-50 the Il'yushin and Beriev OKBs had to deal with numerous problems that were quite new to them, or at least had been encountered on a much smaller scale. These were most associated with the mission avionics and the various ancillary systems. With so many powerful transmitters and sensitive receivers crammed into a relatively small space, the EMC problem loomed large and had to be taken care of



Above: An early artist's impression of the A-50 published in the West. The Western analysts assumed the aircraft would carry the rotodome on a single short pylon, like the Tu-126.

by building a special ground test rig. The Shmel' suite passed extensive testing on the Tu-126LL (LL 'A') testbed. Air and liquid cooling systems, the likes of which had not been seen in the USSR before, were created, as was a special power supply system. Additionally, a large amount of wind tunnel work was done to make sure that the bulky rotodome

did not impair the aircraft's stability and handling to an unacceptable degree.

Western intelligence got wind of the A-50's development in 1983 and the aircraft was allocated the unusually laudatory reporting name *Mainstay*. At first, however, the West had a rather vague idea of what the aircraft looked like; artist's impressions showed a



'30 Red' (c/n 0023436059, f/n 2705), the first production A-50 with the suffix, shows off the horizontal flat-plate strakes characteristic of the type.



Above and below: Two views of A-50 '30 Red' escorted by two Sukhoi Su-30 interceptors from the Russian PVO's 148th Combat & Conversion Training Centre as the trio passes over Poklonnaya Gora in Moscow on 8th May 1995 during the dress rehearsal of the military parade marking the 50th anniversary of VE-Day.





conventional glazed nose and tail gunner's station, and there have been claims that the fuselage was stretched ahead of the wings (which is clearly not the case). An early drawing even showed the rotodome mounted on a single short pylon à la Tu-126, which is certainly not the case.

Meanwhile, a production IL-76 sans suffixe registered CCCP-76641 (c/n 073409243, f/n 0701) was delivered from Air Force stocks to the Beriyev OKB; this aircraft was converted into the first prototype A-50. Note: The

nine- or ten-digit c/ns of IL-76s and A-50s are deciphered as follows. The first two or three digits respectively denote the year of certification: in this case, 07 equals 1977. The next two digits are always 34, a code for factory No.84 introduced in 1952. The remaining five digits do not signify anything at all; the idea is to confuse would-be spies so that the c/n would not reveal how many aircraft have been built. The first two and the final three of these 'famous last five', as they are often called, accrue independently. Additionally, the air-



The photos on this page show A-50 sans suffixe '33 Red' (c/n 0043454618, f/n 4105) landing at its home base, Ivanovo-Severnnyy (top), and being refuelled by a TZ-22 fuel bowser on a KRAZ-258 6x4 tractor unit. The inset shows the badge currently worn by Russian Air Force A-50s based at Ivanovo-Severnnyy AB.



Above: A-50 sans suffixe '41 Red' (c/n 0083483499, f/n 6305) is seen making a visit to Kubinka AB west of Moscow. Note the extremely chipped rotodome, with green paint showing from under the grey top coat.

craft have fuselage numbers (f/ns) showing the batch number and the number of the aircraft within the batch; security is all very well but the manufacturer has to keep track of production.

Wearing a grey/white colour scheme and Soviet Air Force insignia but carrying no tactical code as yet, the first prototype A-50 made its maiden flight at Taganrog on 19th December 1978, captained by test pilot V. P. Dem'-

yanovskiy; M. D. Koreshkov was the engineer in charge of the tests. At the initial flight test phase the aircraft lacked the intended mission avionics, nor was the IFR probe fitted at first. When the Shmel' suite was presently installed, the first prototype effectively turned into a ground test rig for a while, serving for the debugging of the mission avionics which were extremely troublesome at first. ('Debugging the Bumblebee'? Hmm... sounds interesting.)

Two more A-50 prototypes were converted from *Candid-Bs* at Taganrog by October 1983; these were coded '15 Red' (ex-IL-76 sans suffixe c/n 073410311, f/n 0808; ex-registration unknown) and '20 Red'. The latter aircraft is reportedly ex-IL-76M CCCP-86878 (c/n 0013430875, f/n 2209). In due course the first prototype was coded '10 Red'. The aircraft had minor detail differences; for instance, '10 Red' and '15 Red' originally had standard IL-76 style rear portions of the main gear fairings (apart from the APU location).

The first prototype served for performance and handling tests and testing the ancillary systems, the second machine served for verifying the Shmel' suite as such



This fine shot of '42 Red' (c/n 0083484538, f/n 6405) cruising above the clouds shows the colour scheme worn by the A-50 and some of its many antennas. The paintwork on the rotodome is in reasonably good condition on this example.



Above: A-50 sans suffixe '46 Red' (c/n 0033443258, f/n 3205) is pictured at Klin-5 AB north of Moscow, with a MAZ-537 8x8 tractor hooked up. This view shows well the lack of the port entry door and the port forward emergency exit. Note also the dark grey dielectric portions of the rotodome on this aircraft.

and the *Poonkteer* (Dotted line) navigation suite, while the third one was used for ECM gear trials. The main part of the joint trials took place at Vladimirovka AB in Akhtobinsk near Saratov, southern Russia, in 1980 to 1985; the base was the main facility of the Soviet Air Force State Research Institute named after Valeriy P. Chkalov (GK NII VVS – Gosoo-darstvennyy krasnoznamennyy naoochno-issledovatel'skiy institoot voyenno-voz-dooshnykh seel). The State commission holding the trials was chaired by none other than Soviet Air Force C-in-C Air Chief Marshal P. S. Kutakhov, a fact that testified to the degree of importance attached to the A-50. Minister of Aircraft Industry Ivan S. Silayev and Minister of Electronics Industry P. S. Ple-shakov also kept a close watch on the A-50's progress.

Longitudinal stability was found to be poor at an early stage; to remedy this, two large strakes of quasi-triangular planform were added to the aft portions of the main gear fairings on later prototypes and production *Mainstays*. The rearmost portions of the strakes were attached to the cargo ramp and the APU nozzle was located beneath the port strake. Also, test flights showed that in-flight refuelling was all but impossible because the rotodome would hit wake turbulence from the tanker, causing severe buffeting. On internal fuel the A-50 had an endurance of four hours

at 1,000 km (620 miles) from base; maximum take-off weight is 190 tons (418,875 lb).

In view of the generally positive results of the trials, in December 1984 it was decided to launch A-50 production at the Tashkent aircraft factory, which by then had been renamed Tashkent Aircraft Production Corporation. At the factory the 'green' A-50 airframes, which were then delivered to Taganrog for outfitting, bore the designation IL-76A.

Deliveries to the PVO commenced in 1985; the 144th Independent AEW Squadron equipped with A-50s, allowing the Tu-126 to be withdrawn, and the service evaluation stage lasted until 1988. During this time the flights were confined to Soviet territory. In fact, the first actual sighting by a Western combat aircraft over international waters did not take place until 4th December 1987 when a Royal Norwegian Air Force (333 Sqn) Lockheed P-3B Orion from Bodø airbase photographed



'47 Red' (c/n 0043453577, f/n 4005), another A-50 sans suffixe stationed at Ivanovo-Severnnyy. The flightdeck glazing is protected against the sun's ultraviolet radiation by a tarpaulin.



Above: This picture taken by a Royal Norwegian Air Force P-3B was one of the first photos of the A-50 to be published in the popular press.

an uncoded A-50 over the Barents Sea. In 1989 the A-50 officially became part of the inventory. Later, when the existence of new versions was revealed, the original A-50 sans suffixe was redesignated *Mainstay-A* by the NATO.

Production proceeded at a rate of one to five aircraft per year until 1991. For some obscure reason all production A-50s except one were the fifth aircraft in their respective batches. 28 aircraft have been identified by their c/ns and about 25 were believed to be operational in 1992 (this figure includes the later A-50M described below). Confirmed A-50s sans suffixe are '10 Red', '15 Red', '20 Red' (the prototypes), '30 Red', '33 Red', '38 Red', '40 Red' through '43 Red', '46 Red' and '47 Red'. Aircraft coded '31 Red', '32 Red', '34

Red' through '37 Red', '39 Red', '48 Red' and '49 Red' probably belong to the same version.

Until 1990 the A-50s flew primarily routine training missions, periodically participating in major Soviet Armed Forces or joint Warsaw Pact exercises. Initially the 144th Regiment operated from the same base near Siauliai which had been hosted the Tu-126. However, this base soon had to be vacated for political reasons and the *Mainstays* moved north to Beryozovka AB near Pechora on the Kola Peninsula, which the crews were very unhappy about. A-50s were also detached to the Far East Defence District (DD) and to the Crimea peninsula, operating from Black Sea Fleet airbases and checking on the Soviet Union's southern borders in practice missions. Several aircraft were based at Ukurey,

an IL-76 base; in 1999, however, most of the operational *Mainstays* were concentrated at Ivanovo-Severnnyy AB.

In a typical mission the A-50 loiters at about 10,000 m (32,800 ft) on a figure-eight course with 100 km (62 miles) between the centres of the two orbits. The Shmel' surveillance radar can track targets over land and water and detect surface ships as well as aerial targets. V. P. Ivanov claimed the Shmel' has shorter detection range but better resistance to ground clutter than the Westinghouse AN/APY-1 fitted to the Boeing E-3A.

The colour CRT radar displays show targets marked as 'friendly', 'identity unknown' or 'hostile'; 'friendly' aircraft blips are accompanied by the aircraft's tactical code or call-sign and information on speed, altitude, heading and fuel status. The A-50 usually works with Mikoyan MiG-31 interceptors, though the MiG-31's powerful Phazotron SBI-16 *Zaslon* (Shield) phased-array pulse-Doppler radar enables it to act as a 'mini-AWACS' in its own right. Target data is transmitted to the interceptors automatically via data link or by secure voice link. Transmission range to ground C³I centres is 350 km (217 miles) in the metre and decimetre wavebands and 2,000 km (1,240 miles) in the UHF range; SATCOM equipment is used over longer distances.

Pilots are quick to give nicknames to aircraft – affectionate or otherwise. The A-50 was dubbed *shestikrylyy serafim* (six-winged



This uncoded *Mainstay-A* with the IFR probe removed was photographed at Kubinka AB west of Moscow in 1988.



Above: An A-50 *suffix* makes a smoky afternoon approach to Ivanovo-Severnnyy AB. This appears to be a very early-production example, judging by the inboard position of the wing-mounted landing lights built into the flap track fairings, as on the IL-76 *sans suffix*, IL-76M and IL-76T. Note the white nose radomes.



In contrast, this *Mainstay-A* is a later example with the outer landing lights mounted under the wingtips, as on most IL-76MDs and IL-76TDs.



Above: This A-50 ~~carries~~ *suffix* – reportedly also formerly coded '46 Red' (c/n 0043451498, f/n 3805; compare to the one on page 29) – is a test aircraft operated by TANTK Beriye. Note the gold plating on the flightdeck and navigator's station windows. The fuselage number is painted on the engine air intake covers.

seraph, a character from Aleksandr S. Pushkin's poem *The Prophet*), alluding both to the numerous aerodynamic surfaces and the 'eye in the sky' role. Yet the *Mainstay* could easily have earned some disparaging nickname, and with good reason. For one thing, the mission avionics were rather troublesome at first. As a result, the equipment often had to

be switched from automatic to manual mode a dozen times in a mission. Also, the equipment was so bulky that there was no room left for a toilet and a galley (no small thing on a four-hour mission), to say nothing of room to walk around and stretch one's legs.

The A-50 has been involved in several armed conflicts – both directly and indirectly.

During Operation *Desert Storm* in 1990 two *Mainstays* took turns patrolling over the Black Sea, continuously monitoring the operations of Iraqi and Allied forces and keeping a watch for stray US cruise missiles which might be heading towards CIS territory.

The type was also used in both Chechen Wars (1994-96 and 1999-2001), monitoring



Another view of the same aircraft. The contrast between the reasonably intact paintwork on the underside of the rotodome and the chipped paintwork on its upper surface is noteworthy.



Above: A-50U suffix (c/n 0043451498, f/n 3805) seen at Taganrog at a later date, looking much more weathered. Note the stepladder propped up against the rotodome for maintenance access.

the airspace above the war-torn republic and beyond. During the First Chechen War three A-50s were deployed to Privolzhskiy AB near Astrakhan'. Aided by these aircraft, on 21st December 1994 (ten days after the outbreak of the war) the Russian PVO regained complete control of the skies over Chechnya after a break of almost three years that had passed since the demise of the Soviet Union. The objective was to prevent the Chechen guerrillas from using aircraft for bringing in supplies and ammunition – or for the suicide attacks against Russian targets which they had threatened to carry out.

Quite possibly it was the A-50's involvement in the First Chechen War that tipped the scales in the Russian government's decision to grant high state awards to the aircraft's creators. On 16th January 1996 a group of aviation industry and electronics industry specialists and a number of Russian Air Force specialists were awarded the State Prize for Science and Technology. The laureates included A. K. Konstantinov, G. S. Panatov and S. A. Atayants (all TANTK Beriyev) who received the prestigious award in recognition of their part in the development of the A-50.

As a point of interest, Yuriy V. Lonchakov, who captained an A-50 crew as an Air Force Major in 1994-95, went on to become a cosmonaut! On 19th April – 1st May 2001 he flew a mission to the International Space Station aboard the Space Shuttle *Endeavor* as part of the 10th expedition to the ISS.

Ilyushin/Beriyev A-50U AWACS Aircraft

A modest upgrade of the A-50 was brought out in the late 1980s; this version has been referred to as A-50U (*posovershenstvovannyi* – improved or upgraded). Its external recognition features are the lack of the port side navigator's station window (only the starboard one remains), the addition of a small blister fairing on each side of the lower aft fuselage near the cargo ramp and strap-on 96-round chaff/flare dispensers on the rear fuselage sides augmenting the built-in units as a protection against air-to-air and surface-to-air

missiles. These strap-on dispensers are of a different type than the APP-50 pods of identical capacity carried in the same manner by the IL-76MD, being much narrower.

The A-50U prototype was apparently coded '44 Red' (c/n 0093486579, f/n 6505). Other confirmed examples are '45 Red' (c/n 0093493818, f/n 7105), '50 Red' (c/n 0093496899, f/n 7305), '51 Red' (c/n 1003488634, f/n 6609) and '52 Red' (c/n 1013491739, f/n 6905), though '53 Red' (c/n 0093497940, f/n 7405) is probably an A-50U as well. '51 Red' was in the static park at MosAeroShow '92, making the *Mainstay's*



Another view of the same aircraft at Taganrog.



Above: An A-50 seen seconds before touchdown with the high-lift devices fully extended.

Below: A Mainstay-A completes its landing run at Vladimirovka AB, Akhtobinsk, the seat of GK NII VVS. Note the extreme negative stabiliser incidence.



public debut, and at the MAKS'93. Escorted by four Su-27P interceptors from the PVO's 148th Combat & Conversion Training Centre at Savasleyka AB near Nizhniy Novgorod, the same aircraft took part in the military parade in Moscow on 9th May 1995 marking the 50th anniversary of VE-Day. The A-50U's NATO reporting name is *Mainstay-B*.

Il'yushin/Beriyev A-50M AWACS Aircraft (*Izdeliye 2A*) Project

Il'yushin, Beriyev and NPO Vega-M kept working on refining the *Mainstay* – primarily improving reliability and reducing avionics weight. (Soviet avionics weigh about half as much again as their Western counterparts, hence the old joke about Soviet microchips being the largest microchips in the world.) Work on an upgraded mission avionics suite for the A-50 began when the aircraft had just begun its evaluation stage.

On 9th January 1984 the Communist Party Central Committee and the Council of Ministers issued a joint directive ordering the Beriyev OKB to develop the A-50M (*izdeliye 2A*) AWACS. Besides detecting and tracking a greater number of targets at longer range, the Shmel'-2 mission avionics suite was to enable co-operative intercepts by a larger number of own fighters. Additionally, the A-50M was to have a much more capable navigation suite and enhanced ECM capability.

Another important change concerned the powerplant. Instead of the 12,000-kgp (26,455-lb) D-30KP turbofans used hitherto the A-50M was to feature the brand-new D-90 turbofans developed by the Solov'yov OKB for the Tu-204 medium-haul airliner (the engine was renamed PS-90 in 1987). The D-90 had a higher bypass ratio and a cascade-type thrust reverser with a translating cowl on the bypass flow. Initially delivering 12,500 kgp (27,560 lb), it was uprated to 15,000 kgp (33,070 lb) and then to 16,000 kgp (35,270 lb) in due course, which held promise of a major performance boost.

The work proceeded rapidly; the A-50M project was completed before the end of 1984 and a full-size mock-up was built that year. Deputy Chief Designer S. A. Atayants supervised the project development, with I. V. Kalinin as the project chief. As recounted in Chapter 1, the components of the Shmel'-2 suite were put through their paces on the suitably modified Tu-126LL testbed which was now known as the LL '2A'. Meanwhile, the Tashkent aircraft factory started construction of the A-50M prototype which was to enter flight test in 1989.

However, the economic crisis that followed in the wake of Mikhail S. Gorbachov's new *perestroika* policy ruined these plans. On 22nd October 1990 the Council of Ministers issued a directive suspending all further work



Above: The nose of an A-50U, showing the absence of the navigator's station's port side window.

Below: A-50U '50 Red' (c/n 0093496899, f/n 7305) at Taganrog with the rotodome removed.



Another aspect of 'headless' A-50U '50 Red'; note the matt grey sectors near the lateral ECM antennas and the strap-on flare dispenser pods.



Above and below: A-50U '51 Red' (c/n 1003488634, f/n 6609) escorted by Su-27P interceptors from the Russian PVO's 148th Combat & Conversion Training Centre, cruising over the Moscow Region en route to the parade on 9th May 1995 (above) and passing over the public grandstands in Poklonnaya Gora (below).





Above and below: Two views of the same A-50U in the static park of MosAeroShow-92. Note the paint job details on the nose and the extra ECM blisters low in the fuselage aft of the flare dispenser pods.





Top and above: Two more views of A-50U '51 Red' at the MosAeroShow-92, with some of the other exhibits visible beyond.



Above: A different version of the AEW&C Forces badge sported by some A-50s (see page 27).

on the A-50M due to lack of funds. Still, the effort was not in vain. On the one hand, the new powerplant found use on the IL-76MF (the stretched military transport version) and later on the IL-76TD-90VD; on the other hand, the Il'yushin OKB continued pursuing a project of a new-generation AWACS derivative of the IL-76 powered by PS-90 engines.

As a point of interest, in July 1987 *Air International* published a drawing of the A-50 with triple vertical tails (!), wingtip ECM pods and a conventional glazed nose. However, there is no evidence that such a version ever existed. Indeed, Western magazines sometimes published total science fiction about Soviet aircraft, such as the feature in the October 1978

issue of *International Defence Review* with 'artist's impressions' of AWACS and tanker versions of the IL-86 widebody airliner obtained by retouching photos of the prototype (СССР-86000).

Il'yushin/Beriyev A-50E AWACS Aircraft (*Izdeliye AE*)

In the late 1980s the Soviet government agreed to offer the A-50 to foreign customers. Hence in 1988 a single example was converted into the prototype of an export version designated A-50E (*eksportnyy* – export, used attributively) and probably differing from the standard *Mainstay* in avionics fit. The aircraft was demonstrated to Admiral Nadkarni, Chairman of India's Joint Chiefs of Staff, at Kubinka AB west of Moscow in 1988, but no orders followed. Nevertheless, the A-50E programme is still formally alive... see A-50EI below.

The A-50 in Detail

The following structural description applies to the basic A-50 *sans* suffix. Details of other versions are indicated as appropriate.

Type: Long-range airborne early warning and control aircraft. The airframe is of all-metal construction. The aircraft has a flight crew of five (captain, co-pilot, flight engineer, navigator and radio operator) and a mission crew of ten (chief operator/supervisor, radar intercept officers, tracking operators and engineers).

Fuselage: Semi-monocoque stressed-skin fail-safe structure with frames, longerons and stringers; chemical milling is used on some panels. The riveted fuselage structure is made mainly of D16T duralumin; the milled panels adjacent to the fuselage longerons are made of V95 aluminium alloy. The wing and landing gear attachment mainframes are made of V93 aluminium alloy.



A-50U '52 Red' (c/n 1013491739, f/n 6905) shares a hardstand with at least two more *Mainstays*.

Structurally the fuselage is made up of four sections: the forward fuselage (frames 1-18), the centre fuselage (frames 18-67), the aft fuselage (frames 67-90) and the rear fuselage or tail section (frames 90-95). All four sections are joined by flanges. The fuselage cross section changes from elliptical with the longer axis vertical (up to frame 18) to circular (frames 18-64) to elliptical with the longer axis horizontal (frames 64-95). Maximum fuselage diameter is 4.8 m (15 ft 8^{5/8} in) and maximum cross-section area less main gear fairings is 18.09 m² (194.57 sq ft).

The greater part of the fuselage is pressurised, with a pressure differential of $0.5 \pm 0.02 \text{ kg/cm}^2$ ($7.14 \pm 0.28 \text{ psi}$). There are two independent pressurised compartments: the flight crew section (frames 1-14) and the mission crew section (the former freight hold, frames 14-67). To ensure adequate pressurisation the fuselage is sealed in two stages during manufacture. First, U20A elastic sealing tape is placed between the skin and internal structural members (frames and stringers) before they are riveted together; then, two layers of U30-MES-5(k) sealing compound are brushed on over the joint. U20A sealing tape is also used in all rivet joints in the unpressurised areas (such as the wing/fuselage fairing and the main gear actuator fairings) to stop water from leaking in.

The forward fuselage (Section F1) includes the flight crew section and the foremost portion of the mission crew section. The flight crew section is a double-deck structure with the flightdeck (accommodating the pilots, flight engineer and radio operator) above and the navigator's station below it. Both are accessed from the freight hold via a passage on the starboard side with a pressure door and a ladder to the flightdeck.

The flightdeck is extensively glazed, with optically flat birdproof triplex glass panes at the front; the curved side panes and the eyebrow windows are made of Plexiglas. The panes ahead of the captain's and first officer's seats are fitted with dual windshield wipers (top and bottom). The navigator's station has only a single small window on each side (A-50 sans suffixe) or just one window to starboard (A-50U). The glazing (except the windshield panes) features gold plating to protect the crew against the ultra-high-frequency radiation emitted by the radar.

The flightdeck features two sliding windows which can be used as emergency exits on the ground. An inward-opening escape hatch with a window in the flightdeck roof (frames 13-14) provides access to the inflatable rescue dinghy in the event of ditching and generally to the upper surface of the aircraft for maintenance purposes. Additionally, skin areas between frames 5-7 on each side can be chopped out in an emergency.



Top and above: The forward fuselage of A-50 sans suffixe '46 Red' at Klin-5 AB. Note the triple nose radomes and the emergency escape door below the port forward ECM antenna blister.

The forward pressure bulkhead (frame 1) mounts the weather radar dish covered by a detachable GRP radome. A chin radome of similar design encloses the ground mapping radar antenna mounted under the pressure floor of the navigator's compartment; the space between the two radomes is occupied by an electronic support measures (ESM) antenna under a wrap-around GRP fairing. An avionics bay is located ahead of the flightdeck (frames 1-3). The nosewheel well is located between frames 11 and 18.

A forward-hinged (outward-opening) entry door with a circular window is located at the rear of Section F1 between frames 15 and 17. An escape hatch with a sloping chute (accessible both from the flightdeck and the navigator's station) is provided on the port

side between frames 9 and 11; its forward-opening hydraulically actuated door acts as a slipstream deflector when the crew bails out.

The centre fuselage (Section F2) accommodates the mission crew compartment and the modules of the radar set and other mission avionics; the two are separated by a wire mesh screen providing protection from the radar's UHF radiation. The rear portion is cut away from below, starting at frame 56: the cutout is closed by the cargo ramp which is a continuation of the freight hold floor and extends beyond Section F2 to frame 69. The ramp can be opened, allowing the mission crew to bail out in an emergency; it incorporates a U-shaped tail bumper. Section F2 terminates in a flat rear pressure bulkhead (frame 67).



Above: The centre fuselage, port wing and port engines (with the thrust reverser bucket doors open) of A-50U '51 Red'. Note the flap track fairings (four on the inboard flap and three on the outboard one), the anti-soot panels on the engine pylons and the cooling air outlet on the main gear fairing.

Fuselage mainframes 29, 34 and 41 serve as attachment points for the wing centre section's front, middle and rear spars. The wing/fuselage joint is enclosed by a fairing, the front half of which (frames 24-29) includes

the unpressurised air conditioning system bay; it also houses the slat drive motor (in the ACS bay) and the inflatable rescue dinghy (stowed ahead of the ACS bay). A large GRP fairing enclosing satellite communications

antennas is located ahead of this fairing. The rear half of the wing/fuselage fairing (frames 41-45) includes three unpressurised bays housing the flap drive motor, hydraulic equipment and aileron and spoiler controls.

An emergency exit with a circular window is provided on the starboard side at main deck level ahead of the wings (frames 23-24) and two more at upper deck level aft of the wings (frames 58-60). Also, skin areas between frames 19 to 22 and 59 to 61 on each side can be chopped out in an emergency. One more window is provided on each side between frames 50 and 51 (just aft of the wing trailing edge). Again, all windows have gold plating.

Two pressurised stowage compartments for carrying engine covers, wheel chocks, ladders and so on are located under the floor between frames 18 to 35 and 51 to 56. The forward stowage compartment has two downward-opening ventral access doors hinged on the port side (offset to starboard between frames 22 and 24 and on the fuselage centreline between frames 29 and 31). The space between the luggage compartments (frames 35-51) is occupied by the mainwheel wells separated by the fuselage keel beam.

Two elongated fairings of quasi-triangular section are located on the centre fuselage



The rear fuselage of the A-50U, showing the rear radomes and the lateral ECM blisters.

sides between frames 26 and 62, enclosing the main gear attachment points (special projections of fuselage mainframes 37, 41, 45 and 49) and actuators. These fairings accommodate the APU, refuelling panel, DC batteries, liquid oxygen converter, communications and navigation equipment and some of the mission avionics suite's ancillary systems. The rear portions of the lateral fairings carry large horizontal flat-plate strakes with a straight leading edge and an ogival trailing edge. Two ventral fairings of semi-circular section located side by side enclose the mainwheels.

Two tapered inward-canted pylons of symmetrical airfoil section are mounted aft of the wing centre section, carrying a support structure for the RA-10 rotodome. The rotodome itself has a diameter of 10.8 m (35 ft 5 $\frac{1}{2}$ in) and is 2 m (6 ft 6 $\frac{1}{2}$ in) deep. One of its diameters is formed by a metal support structure of almost rectangular planform incorporating a bearing, a hydraulic drive unit and maintenance hatches. The rest of the rotodome is a pair of identical shells of GRP honeycomb construction enclosing the main antenna of the Shmel' radar and the active IFF system. The pylons are built in three portions (leading-edge section, centre section and trailing-edge section); each centre section incorporates a vertical tunnel for the antenna waveguides and power cables.

The unpressurised *aft fuselage* (Section F3) carries the vertical tail attached to mainframes 74, 76, 78, 80, 82, 83, 85 and 86. It also incorporates various aeriels and equipment items.

The *rear fuselage or tail section* (Section F4) is an avionics compartment. Two aft-looking antenna arrays covered by GRP fairings are mounted at the rear of this section.

Wings: Cantilever shoulder-mounted monoplane of basically trapezoidal planform, mounted above the fuselage to leave the interior unobstructed; leading-edge sweep constant, trailing-edge sweep increases on outer wings. Sweepback at quarter-chord 25°, anhedral 3° from roots, incidence 3°, camber -3°, aspect ratio 8.5, taper 1.61. The wings utilise TsAGI high-speed airfoils with a high lift/drag ratio throughout the aircraft's speed range; thickness/chord ratio is 13% at root and 10% at tip. Wingspan is 50.5 m (165 ft 8 $\frac{1}{2}$ in) and wing area 300.0 m² (3,225.8 sq ft).

The wings are all-metal, stressed-skin structures made of D16T duralumin. Structurally they are made up of five pieces: the centre section (which is integral with the fuselage), inner wing sections and outer wing sections, plus tip fairings. The wing sections are joined by attachment fittings on the upper surface and splice plates on the undersurface; the joints are located 2.4 m (7 ft 10 $\frac{1}{2}$ in) and



Above: The rear fuselage and tail unit of A-50U '51 Red'. Note the cooling air intake built into the fin root.



Above: The starboard lateral strake of A-50U '51 Red'.



Another view of the starboard lateral strake of A-50U '51 Red' and the starboard IRCM flare dispenser pod.



Above: The port main landing gear units and APU air intake/exhaust of an A-50; note the soot stains aft of the APU exhaust and the reinforcement plates on the rear fuselage added during an overhaul (these plates are found on many high-time IL-76s).

11.6 m (38 ft 0¹/₁₆ in) from the fuselage centreline. The wing/fuselage joint is covered by a fairing (see above).

The centre section and inner wings are three-spar structures, while the outer wings are two-spar structures. The centre section and inner wing ribs (except Nos 10-11 and 17-18) are parallel to the fuselage axis, with a pitch of 620-650 mm (2 ft 0¹/₂ in to 2 ft 1¹/₂ in); most of the outer wing ribs are at right angles to the rear spar. The wing skins are chemically milled with integral stringers and incorporate

numerous removable access panels (located dorsally on the centre section/inner wings and ventrally on the outer wings) for inspection of the integral fuel tanks. The wing leading and trailing edges feature numerous hinged ventral panels for access to control runs, hydraulic and fuel lines, flap and slat drive shafts and electric cables.

Two engine pylons are attached to each inner wing at ribs 10-11 and 17-18. The distance between the inner pylons is 12.7 m (41 ft 8 in) and the distance between the outer

pylons 21.2 m (69 ft 6³/₄ in), that is, the pylons are respectively 6.35 m (20 ft 10 in) and 10.6 m (34 ft 9³/₄ in) from the fuselage centreline.

The wings are equipped with two-section triple-slotted flaps (one section on each inner and outer wing), five-section leading-edge slats (two inboard and three outboard sections), two-section ailerons (see Control system), four-section airbrakes on the inner wings and four-section spoilers/lift dumpers on the outer wings. The flaps move on external tracks enclosed by fairings (four on each inboard flap and three on each outboard flap). Both inboard slat sections on each side have cutouts to clear the engine pylons when fully deployed. Flap settings are 15° or 30° for take-off and 43°/41° (inboard/outboard) for landing; the slats are deployed 14° (at 15° flap) or 25°. Maximum airbrake and spoiler deflection is 40° and 20° respectively.

Tail Unit: Cantilever T-tail of all-metal stressed-skin construction made of D16T duralumin. The vertical tail consists of a fin and one-piece rudder (see Control system). Sweepback at quarter-chord 39°, fin area (less rudder) 50 m² (537.63 sq ft). The fin is a three-spar structure with 20 ribs set at right angles to the rear spar; the spars are attached to aft fuselage mainframes 74, 82 and 86, with five auxiliary fittings in between. Three rudder mounting brackets are located at ribs 10-11, 21-22 and 33-34; an upper rudder support



The nose landing gear unit of an A-50.

structure extends aft from the rear spar at the top. A small root fillet is attached to the centre and aft fuselage (frames 62-72); it incorporates a large cooling air intake at the root.

The variable-incidence *horizontal tail* is hinged to the fin centre spar and consists of two stabilisers and one-piece elevators (see Control system). Sweepback at quarter-chord 32°, span 17.4 m (57 ft 1 1/4 in), stabiliser area (less elevators) 63 m² (677.42 sq ft). Stabiliser incidence +2°/-8°, adjusted by an electric screwjack located on the fin front spar. Each stabiliser has two spars, 22 ribs and a rounded tip fairing; five elevator mounting brackets are located at ribs 6, 10, 14, 18 and 22. The fin/stabiliser joint is enclosed by a large area-ruled bullet fairing with 23 frames; maintenance hatches are provided between frames 6 and 17.

Landing Gear: Hydraulically-retractable tri-cycle type, with free-fall extension in emergency. Five independent units, each with four wheels on a single axle (that is, two pairs each side of the oleo). The nose unit has 1,100 x 330 mm (43.3 x 13.0 in) KT-159 brake wheels and is equipped with a shimmy damper. The four main units are located fore and aft of the aircraft's CG and have 1,300 x 480 mm (51.2 x 18.9 in) KT-158 wheels. All wheels have multi-disc brakes.

The nose unit retracts forward, the main units inward into two semi-circular-section ventral fairings. During retraction the main-wheel axles rotate around the oleos by means of mechanical links so that the wheels stow vertically with the axles parallel to the fuselage axis; the axles of the forward pair rotate forward and the axles of the aft pair rotate aft. A safety feature prevents the landing gear from being retracted when the oleos are compressed. The main gear fulcrum (main pivot) attachment fittings on fuselage mainframes 37, 41, 45 and 49 are made of VT16 titanium alloy and the side strut attachment fittings of VT22 titanium alloy.

The nosewheel well is closed by two pairs of doors. Each main unit has a large curved main door attached to the fuselage keel beam, small double doors in the lateral main gear fairings near the oleos and a small door segment hinged to the oleo itself. All doors open only when the gear is in transit; this prevents mud, water and slush from entering the wheel wells.

All landing gear struts have oleo-pneumatic shock absorbers and the nose unit has levered suspension. The steerable nose unit can turn ±50° for taxiing; steering is assisted by differential braking, enabling the aircraft to make a U-turn on a runway 40 m (131 ft) wide. Tyre pressure can be adjusted in flight between 2.5-5 bars (36-73 psi) to suit different types of runways (paved or unpaved). Three

jacking points are located beneath the front ends of the lateral main gear fairings (at fuselage frame 27) and immediately ahead of the cargo ramp (at frame 55).

Powerplant: Four Solov'yov (Aviadvigatel') D-30KP Srs 2 turbofans rated at 12,500 kgp (27,560 lbst) for take-off, with a cruise rating of 2,750 kgp (6,060 lbst) at 11,000 m (36,090 ft) and Mach 0.8. As a second choice, D-30KP Srs 1 engines rated at 12,000 kgp (26,455 lb st) for take-off can be fitted, providing they are installed symmetrically to port and starboard. The engine is manufactured by the Perm' Engine Plant.

The D-30KP is a two-shaft turbofan with a three-stage low-pressure (LP) compressor, an 11-stage high-pressure (HP) compressor, a cannular combustion chamber, a two-stage HP turbine, a four-stage LP turbine, a fixed-area jetpipe with a 16-chute core/bypass flow mixer, and a clamshell thrust reverser. Bypass ratio 2.42; overall engine pressure ratio 20 at sea level (engine speed 96%, that is, HP spool speed 10,460 rpm), mass flow at take-off 269

kg/sec (593 lb/sec) at LP spool speed 7,460 rpm. Length overall 5.7 m (18 ft 8 1/2 in), inlet diameter 1.464 m (4 ft 9 3/4 in); dry weight 2,650 kg (5,840 lb). SFC at take-off thrust 0.49 kg/kgp·h (lb/lbst·h), cruise SFC 0.7 kg/kgp·h.

Construction is mostly of titanium alloy, with steel used for some HP compressor parts. The LP spool rotates in three bearings: a roller bearing in the air intake assembly, a ball bearing in the division casing and a roller bearing in the rear support frame. The HP spool likewise has three bearings: a roller bearing in the division casing, a ball thrust bearing at the rear of the compressor and a roller bearing ahead of the turbine.

The air intake assembly has a fixed spinner and 26 cambered inlet guide vanes (IGVs) de-iced by hot air bled from the 6th or 11th compressor stage; variable IGVs are used on the HP compressor to minimise blade vibration. The division casing is made of magnesium alloy. The combustion chamber has 12 flame tubes, two of which feature igniters; the outer casing and duct shroud are split horizontally for access to the flame tubes.



Above: A D-30KP engine (shown here on an IL-76, the type on which the A-50 is based). As the photo shows, the engine can be completely 'denuded' while still on the wing.



The IFR probe and fuel line conduit along the starboard side. Note the probe illumination light.



Above: The chin radome of an A-50U's RLS-P ground mapping radar, with the radome of the forward ESM antenna ahead of it.

HP turbine blades are cooled by engine bleed air, while LP turbine blades are uncooled.

Two ventral accessory gearboxes (front and rear) are provided, one of which has a constant-speed drive for the AC generator and starter. The lubrication system incorporates a fuel/oil heat exchanger and uses VNII NP-50-1-4F synthetic oil or equivalent (VNII NP = *Vsesoyuznyy nauchno-issledovatel'skiy institut nefteproduktov* – All-Union Petroleum Products Research Institute). The engine is started by an STV-4 air turbine starter (*startyor vozdooshnyy*) fed by the APU, ground supply or cross-bleed from other engines; time from start to idle is 40-80 seconds, depending on the outside air temperature (operational limits are $-60^{\circ}/+50^{\circ}\text{C}$; $-76^{\circ}/+122^{\circ}\text{F}$). In-flight starting by windmilling is possible at up to 9,000 m (29,530 ft).

The engines are mounted in individual nacelles on large forward-swept pylons under the inner wings. Strictly speaking, there are no nacelles as such; each nacelle consists of

a one-piece annular forward fairing, four hinged cowling panels and a multi-segment rear fairing. All of these are attached directly to the engine casing, and the nacelle can be disassembled completely or partly, leaving the engine on the wing. The engine attachment lugs are mounted on the division casing and rear support frame.

A Stoopino Machinery Design Bureau TA-6A auxiliary power unit is installed in the rear portion of the port main gear fairing for self-contained engine starting, AC/DC ground power supply and air conditioning. The APU has a dorsal 'elephant's ear' air intake, a one-piece cowling panel and a downward-angled exhaust located beneath the port lateral strake.

Control System: Powered controls with irreversible hydraulic actuators on ailerons, rudder and elevators. Unusually, the actuators are self-contained units, each with its own hydraulic reservoir and electrically-driven

pump. There is a manual emergency backup mode with conventional mechanical controls (push-pull rods, cranks and levers). The mechanical control runs are duplicated (except rudder control) and routed along opposite sides of the fuselage for greater survivability; each of the control runs may be disconnected from the control columns or rudder pedals if it jams. An autopilot is fitted.

Roll control is provided by two-section ailerons and four-section spoilers/lift dumpers on the outer wings. The ailerons have trim tabs on the outer sections and servo tabs on the inner sections. Aileron deflection is $28 \pm 1^{\circ}$ up and $16 \pm 1^{\circ}$ down, spoiler deflection for roll control is 20° .

Pitch control is provided by one-piece elevators; these are single-spar structures with a forward false spar and 61 ribs. Each elevator incorporates a geared tab (ribs 1-23). Each elevator is hinged on one root support and five brackets located at stabiliser ribs 3, 6, 10, 14, 18 and 22 (corresponding to elevator ribs 0, 8, 18, 29, 40 and 51). Elevator deflection is $21 \pm 1^{\circ}$ up and $15 \pm 1^{\circ}$ down.

Directional control is provided by a one-piece rudder which has 50 ribs, a forward false spar, a main spar and an auxiliary spar. The rudder features a servo tab (ribs 1-36) and a trim tab (ribs 36-50). It is hinged on three brackets located at fin ribs 10, 13 and 17 (corresponding to rudder ribs 10-11, 21-22 and 33-34), plus upper and lower supports located aft of the fin torsion box. Rudder deflection is $\pm 28^{\circ} 30'$.

Fuel System: The wing torsion box (centre section, inner and outer wings) is divided into 12 integral fuel tanks and two vent surge tanks; the latter have pressurisation air scoops under the wingtips. The fuel tanks are split into four groups, one for each engine; each group has a service tank from which fuel is fed to the respective engine. All tanks are sealed from within by a coat of sealing compound.

The A-50 has single-point pressure refuelling; the refuelling panel is located on the port main gear fairing between the main gear units. Operation of fuel transfer and delivery pumps is completely automatic. Fuel grades used are Russian T-1 and TS-1 kerosene, Western Jet A-1, DERD.2494 and 2498 (NATO F35 and F43) or equivalent.

A telescopic in-flight refuelling probe is located ahead of the flightdeck glazing and connected to the main tanks by a fuel transfer line running along the starboard side of the fuselage above the entry door. An emergency fuel jettison system is provided.

An inert gas pressurisation system is provided on military versions to pressurise the fuel tanks and reduce the hazard of explosion if hit by enemy fire. This includes an inert gas

A-50 specifications

Length overall (less IFR probe)	46.59 m (152 ft 10 1/4 in)
Wing span	50.5 m (165 ft 8 in)
Height on ground	14.76 m (48 ft 5 in)
Wing area, m ² (sq ft)	300.0 (3,229.2)
Stabiliser span	17.4 m (57 ft 1 1/4 in)
Landing gear track	8.16 m (26 ft 9 1/4 in)
Maximum take-off weight, kg (lb)	190,000 (418,875)
Maximum landing weight, kg (lb)	165,000 (363,760)
Fuel load, kg (lb)	90,000 (198,412)
On-station loiter altitude, m (ft)	9,000-10,000 (29,500-32,810)
On-station loiter time, hours	4
Overland coverage against fighter-type targets, km (miles)	230 (142)
Coverage against large ships, km (miles)	400 (248)
Number of targets tracked at a time	Up to 50
Number of fighters guided at a time	Up to 10
Data link range, km (miles):	
VHF/UHF communications	350 (217)
HF communications	2,000 (1,242)
SATCOM	more than 2,000 km



Above: The pristine-looking rotodome of A-50U '51 Red'. Note the criss-cross lines on the dielectric shells showing where the ribs and stringers are located.
Below: Two technicians are about to climb inside the rotodome.





Above: This model of the A-50I was displayed at one of the international airshows. Note the design of the fixed 'rotodome' with a clean equilateral triangle forming the metal centre portion.



This model of the A-50I makes an interesting comparison with the previous one, featuring a radar fairing with a centre portion shaped like a triangle with cropped angles. Note also the rear fuselage strakes and the wingtip ECM fairings.

generator in the front portion of the starboard main gear fairing breathing through a small air intake.

Hydraulics: Two separate hydraulic systems which power the landing gear, flaps, slats, air-brakes, spoilers/lift dumpers, entry door, cargo ramp and escape chute door.

Electrics: AC power supplied by engine-driven generators and APU generator; the electric system includes DC converters. Backup DC power is provided by battery in the starboard main gear fairing. Ground power receptacle under the front end of the starboard main gear fairing.

Oxygen System: Liquid oxygen (LOX) bottles and a LOX converter are installed in one of the

main gear fairings to provide breathing oxygen for the crew.

Air Conditioning & Pressurisation System:

The crew sections are pressurised by engine bleed air to a pressure differential of 0.5 ± 0.02 kg/cm² (7.14 ± 0.28 psi). Pressurisation air is cooled by two heat exchangers located in the forward portion of the wing/fuselage fairing, with air intakes at the front and efflux gills on the sides.

Fire Suppression System: Three groups of fire extinguisher bottles charged with 114V₂ grade chlorofluorocarbon (CFC) extinguishing agent for each engine. The first shot is triggered automatically by flame sensors in the engine nacelles; the second and third shots are manually operated.

A separate fire extinguisher is provided for the APU bay.

De-icing System: The wing leading edge and engine air intakes are de-iced by engine bleed air. Electric de-icing on the fin and stabiliser leading edges, windscreens, pitot heads and static ports.

Avionics and Equipment

Navigation and piloting equipment: Full equipment for all-weather day/night operation. The A-50 features an SAU-1T-2BT automatic flight control system (*sistema avtomaticheskovo upravleniya*), a DISS-013-S2 or DISS-013-S2M Doppler speed/drift sensor (*doplerovskiy izmeritel' skorosti i snosa*), an RLS-N weather radar in the extreme nose.

The navigation suite comprises a central digital navigation computer, an RLS-P Koopool ground mapping radar installed under the nose, a TKS-P precision compass system (*tochnaya koorsovaya sistema*), a duplex I-P-76 inertial navigation system and an RSBN-7S Vstrecha SHORAN system. The aircraft is equipped with an instrument landing system permitting ICAO Cat II automatic approach, with Koors-MP-2 and Koors-MP-70 automatic approach systems (*koors* = heading), RV-5 and RV-5M radio altimeters linked to a Vektor ground proximity warning system (GPWS), an ARK-15M ADF finder, and SD-75 and SDK-67 distance measuring equipment (*samolyotnyy dahl'nomer* – DME).

Communications equipment: R-855UM, R-855A1 and R-861 UHF radios with dorsal and ventral blade aerials on forward fuselage. Main and backup *Mikron* (Micron) and *Yadro* (Core) VHF radios with antennas buried in the fin bullet fairing. R-851 emergency radio beacon for sending distress signals. SPU-8 and SPU-15 intercoms. An RI-65 automatic voice annunciator (*rechevoy informator*) warns the crew of critical failures (such as fire) and dangerous flight modes.

Mission avionics: The A-50 is equipped with a Shmel' early warning and control suite. This comprises the Shmel' pulse-Doppler search radar with a 360° field of view; a digital data processing system; a radar data presentation system with operators' consoles; an IFF interrogation system; a command link system for communicating target data to 'friendly' fighters or ground and shipboard C³I centres; encoding and decoding equipment; and a data recording system.

IFF system: SRO-1P Parol' (Password, aka *izdeliye* 62-01) IFF transponder with blade aerials are located ahead of the flight-deck glazing and under fuselage section F4. The aircraft also features SOM-64, SO-70 and SO-72M ATC transponders.

ECM and electronic support measures equipment: S-3M Sirena-2 radar homing and

warning system (RHAWs) with aerials on the forward/aft fuselage sides and wingtips. Active ECM system with four teardrop antenna blisters on the forward/aft fuselage sides to give 360° coverage; the A-50U has an additional pair of lateral ECM blisters near the cargo ramp. ESM antennas are built into the fuselage nose and the aft extremity of the fuselage.

Infra-red countermeasures are provided by flare dispensers built into the rear fuselage underside. The A-50U has podded 96-round chaff/flare dispensers firing 50-mm (1⁵⁹/₃₂-in) magnesium flares scabbled onto the rear fuselage sides. The flares can be launched at pre-set intervals, in batches of either two or four at a time.

Data recording equipment: Standard Soviet Mars-BM flight data recorder (FDR) and MS-61B cockpit voice recorder (CVR).

Exterior lighting: Port (red) and starboard (green) navigation lights in wingtips; white tail navigation light on tailcone. Four retractable landing/taxi lights on forward fuselage sides aft of navigator's station and under the wingtips. Red anti-collision strobe lights on top of the fin and under the rear fuselage. Three 26-mm (1¹/₄-in) EKSP-39 four-round signal flare launchers mounted low on the starboard side immediately aft of the ground mapping radar.

Il'yushin/Beriyev/IAI A-50I AWACS Aircraft (*Izdeliye AI*)

In 1994 the Chinese People's Liberation Army Air Force (PLAAF) started negotiations with Russia and Western avionics manufacturers on the conversion of the *Candid* into an AWACS platform. The British company GEC-Marconi offered the Argus 2000 mechanically scanned AEW radar system fitted earlier to the unsuccessful British Aerospace Nimrod AEW Mk. 1, but lost out to Elta Electronics, a division of Israel Aircraft Industries (IAI) which offered a more sophisticated mission avionics suite built around the EL2075 Phalcon surveillance radar. (Phalcon is an acronym for Phased-Array L-band Conformal Radar; 'L-band' means an operating frequency of 1-2 GHz and a wavelength of 30-15 cm (11¹³/₁₆-5²⁹/₃₂ in). Interestingly, China was adamant that it would not buy the Phalcon system unless it was installed on the IL-76. China's determination to create an AEW force of its own was bolstered by the NATO intervention in Yugoslavia in 1999 (Operation *Allied Force*) and US warlike rhetoric directed at China in connection with the traditional tensions over Taiwan.

It took a lot of persuasion before the Russian government authorised the sale of an A-50 to Israel, which was certainly not among the traditional buyers of Russian military hard-

ware. Some sources suggest the Russian government was reluctant to deliver a *Mainstay* to IAI for conversion because it had hoped to sell the A-50 to China in 'as-was' condition. Eventually, however, permission was granted. On 17th June 1997 the Rosvo'orouzheniye arms export agency and TANTK Beriyev signed a deal with IAI at the 42nd Paris Air Show covering the installation of the Phalcon radar in the A-50's airframe – the first military technology deal between Russia and Israel. The resulting combination was known as the A-50I or *izdeliye AI*, the I standing for *izraill'skoye* [*oborodovaniye*] – Israeli equipment. The contract was signed by Rosvo'orouzheniye General Director A. I. Kotyolkin, TANTK Beriyev General Designer G. S. Panatov and IAI President Moshe Keret.

Originally the radar arrays were to be housed in the nose, the tailcone and on the forward fuselage sides in similar fashion to IAI's Boeing 707-320C AWACS equipped with the Phalcon radar (as delivered to the Chilean Air Force), and the result looked really bizarre. However, this was soon abandoned in favour of a more elegant arrangement with a conventional rotodome mounted on twin pylons. Actually the word 'rotodome' is not applicable, as the traditional lens-shaped structure was in fact fixed and the radar beams were



The A-50I prototype (c/n 0093486579, f/n 6505) takes off on its first post-conversion flight at Taganrog on 28th July 1999. Note the 'rotodome' design.



Above: This view shows the upper side of the A-50I's radar fairing with the centre portion shaped like a clean triangle. Note the blade aerial on the fin and above the flightdeck, as well as the absence of the fin root air intake, the lateral ECM blisters and the dielectric panel above the tail radome.

scanned electronically. The design was rather different; the radar fairing's metal centre portion was an equilateral triangle (that is, there were three antenna arrays, each covering a sector of 120°, and hence three dielectric portions instead of two). In Beriev OKB slang the fixed 'mushroom' was known as the *domik* ('little house' or 'bungalow'); in actual fact this appellation was derived from the English

word 'radome'. Also, the 'mushroom' was slightly larger in diameter – 11.5 m (37 ft 8½ in) versus 10.8 m – and the pylons had constant chord instead of tapering towards the top.

The triangular centre portion accommodated the radar set, and cramming the numerous equipment racks, together with their cables and cooling system piping, into the small internal space proved quite a problem.

The entire structure together with the pylons weighed about 13 tons (28,660 lb).

The interior layout was revised to feature a mission crew compartment with ten operator consoles and a rest area with nine seats and utility equipment – an important bonus made possible by the more compact Israeli avionics. The aircraft had a flight crew of five, a mission crew of ten RIOs and a relief crew of



For the initial flight tests the A-50I bore no markings other than a Russian flag on the tail. Unusually, the flight crew escape hatch is outlined in white. The shape of the ventral strakes is clearly visible here.



Above: The A-50I flies over the Bight of Taganrog on the Black Sea during the final approach after an early test flight. Note the wingtip ECM fairings replacing the lateral ECM blisters.

nine. A noise suppression bulkhead separated the crew section from the rest of the cabin. An escape hatch was provided for the mission crew, enabling the RIOs to bail out via the cargo ramp.

The triangular horizontal strakes on the main gear fairings characteristic of the A-50 *sans suffixe*/A-50U were deleted. Instead, the A-50I had twin splayed trapezoidal ventral fins

with rounded corners. The large cooling air intake at the base of the fin, another trademark feature of the standard *Mainstay*, was also omitted, as were the dielectric panel immediately below the rudder and the large ECM blisters on the forward and aft fuselage sides; the ECM antennas were relocated to the wingtips which featured non-standard extended and rounded fairings. On the other

hand, the A-50I had an unswept blade aerial atop the fin (which Russian Air Force aircraft do not have) and a single unswept blade aerial immediately ahead of the dorsal SATCOM fairing was replaced with two small swept aerials. Incidentally, the A-50I carried a total of 71 miscellaneous antennas and aerials, 44 of which were associated with the mission avionics.



The A-50I is about to touch down at Taganrog, showing the powerful high-lift devices fully deployed.



Above: The A-50I, now wearing the Russian registration RA-78740 but no Russian flag, sits at Tel Aviv-Ben Gurion International airport on 26th October 1999 in company with another Russian aircraft, a McDonnell Douglas DC-10-30 of Transaero Airlines.



Centre and above: Two views of the former A-50I, now refitted with Chinese mission avionics and redesignated KJ-2000, in Beijing. The aircraft is now serialised '762 Black' and wears China Flight Test Establishment (CFTE) titles, as does the Xian Y-8 visible in the centre photo.



The first KJ-2000 in flight, showing the CFTE badge on the tail.

The basic A-50's refuelling probe was retained. The PLAAF has converted a small number of Xian HU-6 and H-6DU hose-and-drogue tankers derived from the H-6 bomber (licence-built Tu-16), and these were to support the operations of the A-50I. Changes were also made to the electrics, the mission equipment cooling system, the oxygen system and so on.

In Russia the development of the A-50I was supervised by Ye. P. Konstantinov, with I. V. Kalinin heading the actual design effort. Despite all the previous experience with the *Mainstay*, the A-50I programme necessitated a large scope of research and development work, including wind tunnel tests at TsAGI and a series of static and resonance frequency tests. The latter series was performed on a specially manufactured IL-76 fuselage section mated to the pylons and the 'saucer' radome.

Unique know-how was evolved in the course of this programme. Among other things, for the first time in Russian aircraft design practice TANTK Beriyeve made use of computer-aided design (CAD) software to create a three-dimensional model of the radome and arrange the equipment inside it. This made it possible to integrate the equipment properly, calculate the required length of the wiring runs and check out the ease of maintenance access. It would have been impossible to observe the tight development schedule set forth in the contract if a more conventional wooden mock-up had been constructed.

The next stage was the actual prototype construction, which again proceeded in accordance with the tight schedule stipulated by the contract. To achieve this, TANTK Beriyeve had to enlist the assistance of numerous subcontractors; in some high-priority areas the work went ahead in two or three shifts 'eight days a week', to use a phrase from the well-known song by The Beatles.

The prototype was converted from the abovementioned A-50U prototype (Russian Air Force '44 Red', c/n 0093486579, f/n 6505). Upon removal of the Shmel' mission avionics suite and incorporation of all appropriate structural changes the aircraft made its first flight as the A-50I from Taganrog on 28th July 1999, piloted by a crew comprising captain Gheorgiy G. Kalyuzhnyy, co-pilot Konstantin V. Babich, navigator Yu. N. Gherasimov, flight engineer V. A. Chebanov and test engineer B. G. Dikoon. The first flight was uneventful, the crew voicing a high opinion of the aircraft.

The manufacturer's tests included 15 test flights and seven training flights. At that point the A-50I prototype was devoid of markings, save for a Russian flag on the fin; however, on 26th October 1999 the aircraft was registered RA-78740 (!) prior to the delivery flight to Tel

Aviv-Ben Gurion International airport for outfitting that same day. Shortly afterwards it was placed on the Israeli register as 4X-AGI. Interestingly, TANTK Beriyeve asserts the aircraft was delivered right on schedule, although a Western source claims the delivery was several months late.

The cost of outfitting a *Mainstay* to A-50I standard (not counting the aircraft itself) was estimated at some US\$ 250 million. Apart from the Phalcon radar, the aircraft was to feature a signals intelligence (SIGINT) system capable of eavesdropping on enemy communications and pinpointing the location of enemy radars in the battle area.

RA-78740 was to be the first of four A-50Is ordered by the PLAAF. However, despite being on reasonably good terms with China, the USA saw the A-50I deal as a threat to Taiwan (which Beijing purportedly still aims to recapture by force) and began putting pressure on Israel, trying to stop the deal from coming through. Israel put on a show of defiance at first (then Prime Minister Ehud Barak said IAI would fulfil its contract obligations no matter what) but gave in when the USA threatened to withdraw US\$ 20 billion worth of military aid. Barak lost the 2001 elections and the new Israeli Prime Minister Ariel Sharon officially notified the Chinese government that the A-50I deal was off.

KJ-2000 AWACS Aircraft

What became of the A-50I prototype, you may ask? Israel's pullout from the programme did not upset China's plans completely, and the result was a Sino-Russian AWACS that was a direct successor to the A-50I. The demise of the Israeli programme led Research Institute No.14 in Nanjing to develop an indigenous phased-array radar that would fit into the A-50I's existing radome.

Stripped of the Phalcon system, 4X-AGI was eventually delivered to China on 10th June 2002. In 2002-03 the aircraft was outfitted with a new mission equipment suite at the Xian Aircraft Co. (XAC) plant. Redesignated Kongjing-2000 (or KJ-2000) and serialised '762 Black', the aircraft was taken on strength by the China Flight Test Establishment (CFTE), making its first post-conversion flight in November 2003 with appropriate titles in Chinese and English.

A second KJ-2000 joined the programme in early 2005. Unlike the first aircraft, this was converted from an IL-76MD – or, to be precise, from what is known colloquially as an IL-76MD 'Falsie' with no tail gunner's station. Hence the aircraft retains that version's pointed 'commercial' tailcone with no rear radome and fully glazed navigator's station (and apparently the port entry door as well) and lacks the IFR probe; all other airframe changes match the configuration of the A-50I.



Above: A poor but interesting shot of the grey-painted second KJ-2000, B-4043. Unlike the first aircraft, it was converted from an IL-76MD 'Falsie', not an A-50; hence it lacks the IFR probe and retains a fully glazed navigator's station and a commercial pointed tailcone with no dielectric radome.

The aircraft (c/n 1063420671, f/n 9208) retains the civil registration B-4043 with which it was operated by China United Airlines, the PLAAF's commercial division, and the new airframe components (the dorsal radome assembly, the lower rear fuselage skin replacing the deleted cargo doors, the revised portions of the main gear fairings and so on) were still unpainted when it was first seen as a KJ-2000, standing out against the overall grey colour scheme. The PLAAF intends to field up to four such aircraft.

Il'yushin/Beriyeve/IAI A-50EI AWACS Aircraft

India's involvement with the Russian AWACS goes back a long way. As noted earlier, the A-50E prototype was demonstrated to Admiral Nadkarni, Chairman of India's Joint Chiefs of Staff, back in 1988. However, the aircraft was found to be incompatible with India's existing air defence system. Hence India's Defence Research & Development Organisation (DRDO) started work on an indigenous AWACS based on the IL-76MD (17 of these airlifters had been delivered to the Indian Air Force, and several would be set aside for con-

version). An avionics testbed called ASP (Airborne Surveillance Platform) was converted from a HAL 748-224 Srs 2 twin-turboprop transport (a British Aerospace 748 built under licence by Hindustan Aeronautics Ltd) serialised H-2175, making its first flight on 5th November 1990. However, on 11th January 1999 the ASP crashed near Indian Navy Air Station Rajali (Arakkonam) when the conventionally mounted rotodome separated in flight, striking the tail, and the programme was cancelled.

This tragic event made the IAF reconsider its approach to the *Mainstay*. When the then Vice Prime Minister of Russia Il'ya I. Klebanov visited Delhi in 1999, he signed an agreement envisaging a short-term lease of a single A-50 to the IAF. The aircraft arrived at Chandigarh AB, Punjab, in April 2000. During the lease the aircraft made ten sorties lasting up to six hours each; it was piloted by a Russian Air Force crew but a number of IAF specialists were also on board.

The experience gained during this evaluation period eventually led to an order in 2003 for three *Mainstays* optimised to meet IAF requirements. The new export version was



This rather crude display model illustrates India's proposed AWACS derivative of the IL-76MD with an indigenous radar developed by DRDO. Note the wingtip avionics pods similar to those of the 'aircraft 976'.



Above: The Baghdad-1 AWACS converted from ■ IL-76MD 'Falsie', showing the huge rear radome. The colour scheme is that of Iraqi Airways.

designated A-50EI (*eksportnyy, indeyskiy* – export, Indian). It is basically similar to the ill-starred A-50I, featuring the same Phalcon surveillance radar in a fixed radome; however, part of the mission avionics will be supplied by MNIIP (NPO Vega-M). Another fundamental difference is that the aircraft will be powered by PS-90A-76 turbofans rated at 14,500 kgp (31,970 lbst).

The US\$ 1.1 billion contract was finalised in early 2005. The first of the three aircraft is due for delivery in June 2007; the flyaway price will be around US\$ 350 million.

Baghdad-1 AWACS Aircraft

It is worth noting here that the A-50 has a couple of more distant 'relatives'. The Iraqi Air Force developed several versions of the IL-76 on its own accord – including airborne early warning variants. In 1988 an unidentified Iraqi Air Force IL-76MD 'Falsie' was converted into an AWACS aircraft named Baghdad-1. A Thomson-CSF Tigre surveillance radar manufactured locally under French licence was installed under the aft fuselage in a huge GRP fairing supplanting the cargo doors; the cargo ramp remained but was inoperative. The aircraft wore Iraqi Airways livery but the airline logos and registration were painted out.

Iraqi specialists claimed that the radar, which was manned by four operators, had a scan 'substantially in excess of 180°' and could detect, identify and track targets at up to 350 km (217 miles) range. Since in its basic form the Tigre is mounted on a semi-trailer, changes had to be made to the radar set for airborne installation in order to reduce ground clutter. Tactical information was transmitted in real time by data link or voice link; the aircraft also featured indigenous radio and radar ESM equipment.

Adnan-1 (Baghdad-2) and Adnan-2 AWACS Aircraft

Quite obviously the unconventionally-located radar antenna of the Baghdad-1, besides having a limited scan, was extremely vulnerable on take-off and landing. Realising this, the Iraqis fitted another IL-76MD 'Falsie' with a conventional rotodome mounted on twin pylons immediately aft of the wings. This aircraft also had the Tigre radar; the rotodome had a diameter of some 9 m (29 ft 6 in) but the metal centre section was much wider and the dielectric portions smaller than on the Soviet types. Two long trapezoidal splayed strakes were fitted to the aft fuselage sides to compensate for the destabilising effect of the

rotodome. It was claimed that the integration and debugging effort had been undertaken entirely in Iraq but Western aviation experts took this with a pinch of salt.

Originally known as Baghdad-2, the second Iraqi AWACS conversion was soon renamed Adnan-1 in memory of Defence Minister General Adnan Khajrallah Talfah killed in a helicopter crash in May 1988. It was soon joined by a third AWACS, an identically converted IL-76MD 'Falsie' named Adnan-2.

All three Iraqi AWACS conversions were actually used operationally in late 1988 during the early stages of the Gulf War (the Iraqi invasion of Kuwait). When Saddam Hussein realised he was losing the war, all three AWACS *Candidis* and many other Iraqi aircraft were flown to neighbouring Iran in January 1991 to escape destruction by the Allies. However, the Iranians took advantage of this windfall, interning the aircraft (since Iran was neutral) and subsequently appropriating them as reparations for damages sustained in the preceding war with Iraq in 1980-88.

Il'yushin IL-150 AWACS Aircraft (Project)

In 2000 the Il'yushin OKB proposed an AWACS aircraft based on the IL-76MD-90 (a version of the IL-76MD re-engined with PS-90A-76s) and tentatively designated IL-150. This indicates that the aircraft is basically a PS-90 powered A-50 – a follow-on to the A-50M project and perhaps a stepping stone towards the A-50EI.

Il'yushin/Beriyev 'Aircraft 976' Radar Picket Aircraft (SKIP, IL-76SK)

While we are on the subject of the A-50, mention should be made of an aircraft which was developed by the same OKBs (Il'yushin and Beriyev) and is rather similar externally but fills



■ view of the Adnan-1 (formerly Baghdad-2) AWACS, showing the wide metal centre portion of the rotodome.

■ quite different role. Monitoring and recording systems operation during test launches of ballistic and cruise missiles is something of ■ problem, since conventional data recorders ■ highly unlikely to be retrieved intact when the missile drops – or blows up. The only reliable method is to transmit systems data by means of telemetry which is picked up by ground measuring stations or specially equipped aircraft.

Initially the Flight Research Institute named after Mikhail M. Gromov (LII – *Lyotno-issledovatel'skiy institut*) in Zhukovskiy used the IL-18SIP (*samolyotnyy izmeritel'nyy poonkt* – airborne measuring station) based on the IL-18A four-turboprop airliner. When the IL-18SIP (CCCP-27220) had to be retired in due course, LII had to find a replacement. First, two *Candid-Bs* – IL-76 sans suffixe CCCP-86721 (c/n 073410271, f/n 0708) and IL-76M CCCP-86024 (c/n 083414425, f/n 1107) – were converted into almost identical telemetry pickup aircraft known as 'aircraft 676' and 'aircraft 776' respectively. These shared some of the equipment with the IL-18SIP and its new-build production version, the IL-20RT, including ■ large rear-mounted antenna in a characteristic thimble radome (supplanting the tail turret on the *Candid*s).

Operational experience with 'aircraft 676' and 'aircraft 776' led to the development of a



Above: This model of the '976' carrying 'IL-76SK' nose titles was displayed at one of the Moscow airshows.

specialised radar picket version of the IL-76MD designated 'aircraft 976' or SKIP (*samolyotnyy komahndno-izmeritel'nyy poonkt* – airborne measuring and control station, AMCS). The unusual designation is probably derived from the aircraft's product code which could be *izdeliye* 976. Development was completed in the mid-1980s. Since the aircraft was developed jointly with TANTK Beriyeв, it has been erroneously referred to in the West as 'Be-976' (some sources call it 'Myasishchev-976', although the Myasishchev Design Bureau had nothing to do with this aircraft).

'Aircraft 976' is superficially similar to the

A-50, featuring an identical RA-10 rotodome – which, incidentally, has earned it the nickname *Pogahnka* (Toadstool) at LII. Like the A-50, it has satellite communications and data link antennas in ■ large dielectric fairing ahead of the wings and two stroke aerials aft of the nose gear.

But here the similarity ends. The AMCS retains the standard navigator's station glazing, the tail gunner's station (used as an equipment operator's station), the cargo doors and the port side entry door. The main gear fairings and APU location are likewise unchanged as compared to the IL-76MD, and



Another view of the ■ model. In reality RA-76453 still carries '976' nose titles. The aerials on the ■ and the sides of the fin are omitted here.



Above: СССР-76456, the fifth and final 'aircraft 976', on the hardstand at LII, Zhukovskiy, during the MAKS-2001 airshow. The glazed nose and the port entry door are easily visible. Note the chipped paintwork on the rotodome, a problem the '976' shares with the A-50.



This shot of the same aircraft sitting at the end of Zhukovskiy's runway 12, with a bend of the Moskva River in the background, was the first published photo of the '976'.



Above: The first 'aircraft 976', CCCP-76452, makes a low pass over the LII airfield with the flaps set for take-off. The quadruple nose probes and the characteristic wingtip pods are clearly visible.



A three-quarters stern shot of the aircraft, showing the rear radome replacing the tail turret and the triple L-shaped aerals on the fin (hence the unusually high position of the Soviet flag).



Above: 'Aircraft 976' CCCP-76452 in the static park at the MAKS-97 airshow. Note the ventral strake aerals, the nose probes and L-shaped aerals, and the fuselage number 50-02 stencilled on the engine air intake covers.



RA-76453, shown here on a rain-soaked apron at the MAKS-95, is the only example to receive the Russian prefix and the LII badge (visible under the '976' nose titles).



Above: Another view of RA-76453 parked on the north side of LII's airfield, with the runway in the foreground.



A magnificent landing shot of 76455. This example also wears the Russian flag but has no prefix.



Above: One of the many mission equipment operator consoles in the cabin of 'aircraft 976'. All of the operators face either the nose or the tail.



Another operator workstation in the cabin of the '976'. The workstations have cathode-ray tube displays.

the A-50's characteristic horizontal strakes have been omitted. This is probably because the equipment installed in the freight hold and rotodome differs; hence weight distribution is also different and the rotodome does not have such a drastic effect on the longitudinal stability.

The UKU-9K-502 tail turret is replaced by a hemispherical radome which is shorter and more bulbous than the rear 'thimble' of 'aircraft 676'/'aircraft 776', and the PRS-4 gun ranging radar above it is deleted. Two massive cylindrical equipment pods are installed

at the wingtips, carrying the navigation lights; their front and rear portions are dielectric, enclosing flat-plate antennas. As on 'aircraft 676'/'aircraft 776', four long probes are located around the navigator's station. Three L-shaped aerials are found on each side of the fin (the predecessor had one such aerial on each side). Four L-shaped aerials of a different type are mounted ahead of the flight-deck glazing, the inner ones facing forward and the outer ones aft; the main gear fairings carry several blade aerials. The cargo cabin is crammed with data processing and storage

equipment which appears to be modular, allowing the aircraft to be configured for specific missions (part of it was mounted on the cargo ramp on some aircraft).

Five new IL-76MDs built in 1986 and 1987 were converted to 'aircraft 976' standard. Despite their near-military role, they wore Aeroflot colours and were registered CCCP-76452 (c/n 0063465965, f/n 5002), CCCP-76453 (c/n 0063466995, f/n 5009), CCCP-76454 (c/n 0063469074, f/n 5209), CCCP-76455 (c/n 0063471125, f/n 5402) and CCCP-76456 (c/n 0073474208, f/n 5602); three out of five aircraft still have the old Soviet prefix and flag as of this writing. The only deviation from 1973-standard Aeroflot livery is that nose titles read '976' instead of 'IL-76MD' and the flag is carried higher on the tail.

Individual aircraft differ in detail. Thus, at least three (CCCP-76452, -76453 and -76455) have an orange-painted cylindrical fairing of unknown purpose (looking like something unprintable) protruding down immediately ahead of the cargo ramp. CCCP-76452 also has L-shaped aerials mounted above and below the wingtip pods.

The AMCS is used to monitor trajectories and systems status of both manned and unmanned aerial and space vehicles in real time. Unmanned aerial vehicles (UAVs) can be remote-controlled; a self-destruct command can be transmitted if an experimental missile goes haywire and heads where it shouldn't. Telemetry data is processed, taped and transmitted in real time to ground control and telemetry processing centres by radio or satellite link, thus obviating the need to build additional facilities in remote areas. Tracking range is 1,000 km (621 miles) and trajectories are measured to an accuracy of 30 m (100 ft). The six telemetry channels have a data transfer rate of 2 million baud (2 Mb per second). Endurance is 8 hours.

'Aircraft 976' are known to have been used in the Tu-160 strategic missile carrier's trials programme, monitoring test launches of Kh-55M (AS-15 *Kent*) cruise missiles. LII claims the AMCS may also be used for ecological monitoring 'and other purposes' (sic).

The existence of 'aircraft 976' was revealed on 16th August 1988 during the Aviation Day flypast in Zhukovskiy. Spectators sitting on vantage points near LII's perimeter fence could see all five aircraft parked in a neat row at the end of the old runway where it joined the active 5,000-m (16,400-ft) runway 12-30. The A-50, as already mentioned, had been sighted in late 1987, and of course Western journalists believed the 'toadstools' to be prototypes of the A-50 (what else could they think?); it was some time before the matter was clarified. Nevertheless, 'aircraft 976' received the reporting name *Mainstay-C1*.

Of course the Powers That Be were aware

that there was no point in concealing the existence of the AMCS any longer. Hence LII's display stand at the Moscow Aerospace '90 trade fair held at the VDNKh fairground (*Vystavka dostizheniy narodnovo khoziaystva* – National Economy Achievements Exhibition) in October 1990 featured a photo of 'aircraft 976'. On 23rd May 1991 the Soviet Weekly gazette ran a story about LII titled *Secret Centre of Excellence* and featuring, among other things, a photo of CCCP-76453. The caption read: 'The Il'yushin-76 flying laboratory, used to study the chemical composition of the atmosphere'. This was nonsense, of course, as the rotodome obviously had nothing to do with 'studying the chemical composition of the atmosphere'!

A year later the same aircraft was in the static display at MosAeroShow '92 – this time with a tablet truthfully saying 'airborne measuring and control station' but containing no data whatever. Since then 'aircraft 976' has been a regular participant of Moscow airshows. So far only two aircraft (RA-76453 and 76455 – the latter has no prefix) carry the Russian flag.

Curiously, a model of RA-76453 displayed at MAKS-95 and Farnborough International '96 had 'IL-76SK' (*spetsial'nyy komandnyy [samolyot]* – special command aircraft) nose titles. This was a proposed development of 'aircraft 976' to be used for monitoring launches of the Burlak suborbital launcher carried by the Tu-160SK, which has not materialised so far.

In recent years the 'aircraft 976' have been sitting idle due to the dire situation the Russian aerospace industry found itself in. Since the aircraft were low-time airframes, a decision was taken to convert one of them into an engine testbed broadly similar to LII's own IL-76LL testbeds and sell it to China. In early 2004 CCCP-76456 had the rotodome and associated pylons removed; the lower pair of nose probes was also removed, as were the upper and lower pairs of L-shaped aerials on the fin, but two of these aerials were relocated to a position immediately ahead of the tail radome. The No.2 (port inboard) D-30KP was replaced by a special pod housing the experimental engine. Curiously, the air intake of this pod features a shutter apparently intended to prevent the development engine from windmilling when inactive – something that was not found on the IL-76LL, where the development engine was carried in its intended standard nacelle (or something similar to it). As on the IL-76LL, test equipment heat exchangers in characteristic fairings are installed on the fuselage sides immediately aft of the wings. After a period of preliminary flight tests at LII the aircraft (still registered 76456) is due for delivery to the China Flight Test Establishment in 2005.



Above: Two more mission equipment operator workstations on the 'aircraft 976'.



Above: Part of the equipment and associated wiring bundles is located above the 'false ceiling' of the cabin (at the level of the detachable upper troop deck of the IL-76MD).



CCCP-76454, shown here on the LII airfield's south side, with a Mil' Mi-6 in the background, was probably the least-photographed example of the '976'.



Top and above: Former 'aircraft 976' 76456 following conversion into ■ engine testbed for the China Flight Test Establishment. As these views show, the rotodome and many of the airdrops have been removed, and a test engine pod replaces the No.2 D-30KP. Note the test equipment heat exchangers.

The Strangest Tail of All

Antonov An-71 AWACS Aircraft

By the end of the 1970s the West had developed and fielded a new generation of AWACS aircraft. The Boeing E-3A Sentry, which was then in service with the USAF and the NATO Airborne Early Warning Force (NAEF), had been joined by the Grumman E-2A Hawkeye shipboard AWACS aircraft. Apart from the US Navy, the Hawkeye was delivered to Israel and Japan, which operated it as a shore-based tactical AWACS aircraft. The Israel Defence Force/Air Force's ascendancy over the air forces of the Arab nations during the war in Lebanon in 1982 was due in no small degree to the capabilities of the E-2A which was used to monitor the airspace over the war zone.

At that time the Soviet Air Force had only the Tu-126 AWACS, which was getting long in the tooth; as for tactical AWACS aircraft intended for battlefield surveillance and control, they were non-existent in the Soviet Union. Perceiving the need to remedy this situation, in 1982 the Ministry of Defence teamed up with the Ministry of Aircraft Industry and the Ministry of Electronics Industry, urging the Soviet government to initiate development of an indigenous counterpart to the Hawkeye. In due course the Council of Ministers issued a directive concerning an R&D programme for a theatre AWACS. This document named KMZ 'Trood' (*Kiyevskiy mashinostroitel'nyy zavod* – the 'Labour' Kiev Machinery Plant) as the organisation holding overall responsibility for the project; this was the then-current name of the design bureau founded by Oleg Konstantinovich Antonov and known until the mid-1960s as the GSOKB-473 (*Gosoodarstvennoye soynoye opytno-konstruktorskoye byuro* – State Union Experimental Design Bureau). As in the case of the Tu-126 and the A-50, the Moscow Research Institute of Instrument Engineering (MNIIP, aka NPO Vega-M) was responsible for the mission avionics suite of Antonov's future AWACS.

The government placed extremely stringent demands for the new AWACS; furthermore, the designers had to meet very tight deadlines. The objective was to create a shore-based aircraft at least equal in its capabilities to the then-latest version of the Hawkeye, the E-2C. The availability of such an aircraft would boost the combat efficiency of

the Soviet Air Force's fighter and attack units immensely.

The specific operational requirement (SOR) was formulated in 1982-83 by the VVS and the PVO, assisted by the aviation industry's research establishments and manufacturing enterprises, and included the following properties:

- an endurance of four and a half (or five) hours;

- the ability to detect low-flying aircraft and other low-observable aerial targets at long range;

- the ability to track at least 120 targets at a time;

- the ability to detect radar pulse emitters within a wide range of operating frequencies, determine their type and take bearings on the emitters, displaying appropriate information at the mission crew's work stations;



Top and above: This display model of the An-71 was demonstrated at one of the Moscow airshows.

- the ability to work in co-operative intercept mode both with current fighter types and with prospective next-generation fighters that are still on the drawing boards;

- the ability to transmit information simultaneously to command centres and to automated control systems within the frameworks of the VVS, the PVO, the Navy and the Ground Forces;

- the ability to operate in various geographical and climatic zones, in visual and instrument meteorological conditions, day and night, at ambient temperatures up to +50°C (122°F);

- the ability to operate for lengthy periods away from established maintenance bases.

Since aircraft of this class had not existed in the Soviet Union before, choosing the general concept – that is, selecting the aircraft's general arrangement, composing the mission equipment suite and defining its parameters, setting the development schedule and choosing the future aircraft's operational tactics – was of prime importance. This was a major task and took time. At length, in the fourth quarter of 1982 the military completed the SOR, while the Antonov OKB (as we will call it hereinafter for the sake of convenience) came up with a technical proposal envisaging two distinct configurations of the machine differing in avionics fit. Version 1 had a decimetre-waveband radar with an antenna array located in a dorsal fairing, while version 2 was equipped with a centimetre-waveband radar whose antenna arrays were positioned in the nose and in the tailcone.

Several aircraft came into the picture at this stage as possible platforms for the future AWACS. The list included the venerable An-12 four-turboprop medium transport, the An-32 twin-turboprop light transport, the An-72 twin-turboprop short take-off and landing (STOL) light transport and even a purpose-built airframe designed for this role. The designers contemplated each aircraft's structural and aerodynamic layouts, its power/weight ratio and the chances of obtaining the required performance with this aircraft as the basis.

Apart from the rather obvious fact that the large radar antenna(s) would spoil the aircraft's aerodynamics – perhaps unacceptably, – there was the question of whether the engines were powerful enough to lug the mission equipment and could furnish enough electric power for it. Thus, each of the 'candidates' passed wind tunnel tests in model form with both versions of the mission equipment (and hence different radomes). The objective was to find the best location for the radome with due regard to aerodynamic interference with the fuselage, wings and tail and minimise the deterioration of stability, control and lift/drag ratio.

By March 1983 the MoD had assessed all the alternative project configurations, selecting the dorsal placement of the radar antenna in a conventional 'saucer' rotodome. At this point the 'mini-AWACS' was allocated the designation An-71, and some sources state that the programme bore the codename Kvant (Quantum). The revised SOR presented by the military stated expressly that the aircraft was to be based on the An-72 light military transport. It should be noted that the Antonov OKB had taken such a serious approach to the preliminary design (PD) stage that the usual advanced development project (ADP) and full-size mock-up stages could be skipped, allowing the detail design stage to begin immediately.

The appearance of the An-71 effectively crystallised at the ADP stage. The chief factor affecting the choice of layout was the need to position the radar antenna so that its 'field of view' would not be obscured by elements of the airframe. Thus, the initial layout with a conventionally located rotodome on a pylon above the fuselage was rejected in favour of an unusual arrangement with the rotodome perched on top of the vertical tail; taking a number of factors into consideration, this layout held greater promise.

Of course, this entailed designing the rear fuselage and tail unit from scratch (no pun intended), as the An-72 had a T-tail and a rear loading hatch weakening the fuselage structure. To keep the aircraft's centre of gravity within acceptable limits the vertical tail was forward-swept, resulting in an utterly unique arrangement (although an early project study of the Boeing E-3 – then provisionally designated EC-137A – also envisaged a tail-mounted rotodome). The vertical tail's thickness and chord were greatly increased; as was the case with the An-72, the rudder was double-hinged, the forward segment deflecting automatically to compensate for the thrust asymmetry caused by an engine failure. Both rudder segments were split into upper and lower halves.

The An-72's trademark feature was the placement of the Lotarev D-36 turbofans ahead of and above the wing leading edge to use upper surface blowing (the so-called Coanda effect) as a means of achieving the required short-field performance. The new low-set tailplanes thus found themselves in the engines' exhaust wake and would be subjected to strong vibration. To minimise this undesirable phenomenon the horizontal tail was given strong dihedral; also, the new rear fuselage was upswept, raising the horizontal tail an additional 0.5 m (1 ft 7¹¹/₁₆ in) above the fuselage waterline.

Still, it may well be said now that the An-71's handling characteristics turned out to be markedly different from those of the An-72,

as the rear fuselage (and hence the moment arm of the tail unit) was some 4 m (13 ft 1 in) shorter. Longitudinal and directional stability and control were generally inadequate, and there were other problems into the bargain.

The An-71 was powered by Muravchenko (ZMKB Progress) D-436K turbofans – a version of the D-36 uprated to 7,500 kgp (16,530 lbst). Nevertheless, this was not enough to achieve the stipulated field performance especially in the event of an engine failure. Therefore, a small turbojet – a Kolesov RD-36A delivering 2,900 kgp (6,390 lbst) developed at the Rybinsk Engine Design Bureau – was buried in the rear fuselage to act as a take-off booster, breathing through a dorsal air intake and an S-duct. When not in use the intake was closed by an aft-hinged door located in a flattened teardrop fairing to prevent windmilling during cruise.

Other changes worthy of note included a redesign of the front ends of the main landing gear fairings (well, in effect this was a single blended fairing wrapped around the fuselage underside) which now housed the mission equipment's heat exchangers. The rest of the airframe was taken from the An-72 in as-was condition. The An-71 had a crew of six – two pilots, a flight engineer and three mission equipment operators.

Detail design of the An-71 began in the first quarter of 1983. The development schedule called for this stage to be completed in the third quarter of 1984, with preparations for production proceeding in parallel in January–September 1984. The first prototype's sub-assemblies were to be manufactured through 1984; final assembly and systems installation were to begin in 1985, and the aircraft was to be rolled out in the second quarter of that year.

Meanwhile, on 9th January 1984 the An-71 'gained official status' when the Council of Ministers issued a directive ordering the aircraft's construction. By then the design work was well advanced. Back in the autumn of 1982 A. I. Naoomenko was appointed chief project engineer. Later he was joined by subordinate project chiefs responsible for specific areas of the 'pie'; Yu. I. Khorolets was responsible for the airframe construction ('pie-crust'), S. P. Fedin for the electronic wizardry ('gravy and meat'), E. A. Sholomitskiy for the air conditioning and cooling systems and S. A. Fil' was in charge of the flight tests ('the eating?'). At the Antonov OKB's flight test facility at Kiev-Gostomel' airfield, engineers I. I. Radautsan, A. Yu. Dolenko and A. M. Zagoomennyy were responsible for the flight tests. Pyotr V. Balabooyev supervised the An-71 programme as a whole and solved the toughest design concept problems; he became the OKB's new General Designer in 1984 when Oleg K. Antonov passed away.



Above: The first prototype An-71, CCCP-780151, seen during tests to determine the radar's scatter pattern, hence the cubes attached to the airframe. Note the heat exchanger air intake and air outlet in the starboard landing gear fairing.



A view of the first prototype's tail unit/rotodome assembly. Note the sweptback stabilisers and horn-balanced elevators.



Above and below: An-71 CCCP-780151 parked in the open for the radar scatter pattern tests. The vehicle parked next to it is a ground power unit on a Ural-4320 6x6 diesel lorry.





Above and below: Two more views of the first prototype An-71 during radar scatter pattern tests. Note the nozzle of the booster engine under the rear fuselage, tailcone housing the spin recovery parachute (with a ventral lock fairing) and the sweptback fin root fillet.





The first prototype An-71 is rolled out at Kiev-Svyatoshino on 23rd June 1985; the tractor is a K-710 Kirovets.

As already mentioned, the An-71 was conceived as a shore-based aircraft. In the mid-1960s, however, the Soviet Navy embarked on an ambitious conventional take-off and landing (CTOL) aircraft carrier development programme in a move to challenge the US Navy's supremacy in the world oceans (a move that eventually came to nothing, but that's a different story). Hence in 1982-83 the Antonov OKB undertook research and development work on a shipboard version of the An-71 to be based aboard nuclear-powered CTOL carriers – an aircraft that would have been a direct counterpart of the Hawkeye in function, if not in design.

This chapter of the An-71 programme is a story in itself. The general operational requirement for a carrier-based mini-AWACS issued by the Navy envisaged a compact aircraft with folding wings to save deck space, good field performance and an adequate payload to accommodate the mission equipment. Not a single one of the aircraft types then operated by the Soviet Air Force or the Soviet airline Aeroflot could 'fit the bill'; a new machine was needed. Thus, four of the nation's aircraft design bureaux – Antonov, Beriev, Myasishchev and Yakovlev (the projects of the latter three are described separately in Chapter 4) – joined the contest.

The Antonov project received the tentative designation An-75 (see end of chapter). Two ways were considered: a straightforward adaptation of the An-71 then under development, or a 'clean sheet of paper' design

tailored to carrier requirements. However, 'navalising' the An-71 turned out to be not so straightforward after all, requiring major structural changes. The overwing placement of the engines, inherited from the An-72 and meant to improve field performance, now turned into a disadvantage, hampering the obligatory wing-folding procedure. If the engines were moved to an underwing position (as was eventually done on the An-74TK-300 utility aircraft, one of the latest members of the An-72/An-74 family), this would free up space above the fuselage not only for the folding wings but for the rotodome as well, and the result would effectively be a new design.

Having more than enough other priority programmes to take care of, the design staff of the Antonov OKB nonetheless persisted with the An-71 navalisation project. An official SOR for this aircraft appeared in the fourth quarter of 1983, followed in the third quarter of 1984 by a technical proposal. According to the OKB, the project set out in the proposal fully met the Navy's requirements. However, the thrust/weight ratio of the An-71 was insufficient to permit take-off from the 'ski jump' structure at the bows common to all Soviet CTOL aircraft carrier projects. Two options were open: to use a deck catapult or to increase the available thrust by installing an additional pair of jet boosters. Now the first Soviet CTOL aircraft carrier (laid down as the SNS *Leonid Brezhnev*, then rechristened SNS *Tbilisi* and finally SNS *Fleet Admiral Kuznetsov*) had no deck catapults, relying

solely on the 'ski jump'; the larger carrier SNS *Ulyanovsk* was to feature steam catapults but she was never completed.

That said, the prospects of the navalised An-71 appeared very questionable. After assessing the project with due regard to the operating conditions on board the ship, the required modifications to the An-71 and the weight of its mission avionics the Navy pronounced further development of this aircraft inexpedient. Considering the number of other programmes the Antonov OKB had in the making, it was deemed advisable to task one of the 'competitors' – the Yakovlev OKB – with creating a 'clean sheet of paper' design (the Yak-44 project) and performing the complete design cycle.

In the meantime, however, work on the 'landlubber' version continued unabated. The Antonov OKB's prototype construction facility at Kiev-Svyatoshino airfield started manufacturing three An-71 airframes at once – two flying prototypes and a static test article. The first prototype was converted from the original first prototype of the An-72 (c/n 004 – that is, Batch 0, 04th aircraft in the batch, as the preceding three airframes were static and fatigue test articles). Making its maiden flight on 31st August 1977 with the custom registration CCCP-19774 (that is, year of production 1977, 4th airframe built), the aircraft was later reregistered CCCP-83966 (the 839xx batch was one of those used by MAP) and then CCCP-72004. It was eventually damaged beyond repair in

a landing accident at Kiev-Gostomel' but was sufficiently intact to lend itself as a candidate for conversion.

Apart from grafting on the new rear fuselage and tail unit/rotodome combo, the extensive rebuild involved cutting up the fuselage at frame 14 (that is, a short way aft of the entry door) and inserting a 990-mm (3 ft 2⁶³/₆₄ in) 'plug' to provide enough room for the mission crew. The original *Gradiyent* (Gradient) weather/navigation radar in the short radome characteristic of Kiev-built An-72 prototypes gave place to a new radar in a new and longer radome bulged at the bottom, which promptly earned it the nickname 'pelican nose'. An identical radome was later fitted to the An-74 prototype in the days when it was registered CCCP-72003. Upon conversion the An-71 received a new construction number, 01.

The static test article (c/n 02) due for delivery in April 1985 was again rebuilt from a Kiev-built An-72 – the original static test airframe (c/n 001). The second flying prototype (c/n 03) due for delivery in the first quarter of 1986 was a bit different in this respect, being built from suitably modified stock An-72 airframe components manufactured by the Khar'kov Aircraft Production Association (KhAPO – *Khar'kovskoye aviatsionnoye proizvodstvennoye ob'yedineniye*).

Due to the programme's high priority the people at the Antonov OKB did their utmost to maintain the prototype construction and test schedule unerringly. However, NPO Vega-M, which was responsible for the mission avionics suite, was working just as hard. In fact, one might be justified in saying that *three different mission avionics suites* were consecutively developed for the An-71, so widely different were their design and performance parameters.

Version 1 capitalised on the search radar which was the core of the system. The radar set was housed in the forward and rear bays of the centre fuselage, while the antenna was accommodated in the rotodome.

The original radar suite was installed in the first prototype immediately upon completion of the initial flight tests during which the An-71's flight performance and handling were checked. A brief initial period of tests gave results so disappointing (primarily with regard to background clutter) that the need to redesign the radar itself and the associated computers became obvious. The engineers at NPO Vega-M succeeded in making the necessary changes to the suite's components within a very brief period, and the *summa summarum* of these changes was, in effect, a new suite which was fitted to the second prototype; among other things, it included additional modules which had to be accommodated in the centre fuselage section for want of space.

The second suite worked better. However, appetite comes when eating, and the military are never satisfied; the customer was clamouring for higher performance, placing ever more stringent demands as regards the AWACS aircraft's integration with the interceptors and surface-to-air missile systems for which it was to provide guidance, and as regards automation of the mission crew's work. It was back to the drawing board; NPO Vega-M had no choice but to design a third mission avionics suite, which was retrofitted to the third prototype while the aircraft was in lay-up.

The institute built more than 30 custom-made test rigs to verify the An-71's mission avionics. Among other things, a special rig served for testing the filling procedure of the suite's liquid cooling system. Huge importance was attached to protecting the crew from the dangerous electromagnetic pulses (EMP) emitted by the equipment – a problem made especially acute by the aircraft's small size. Thus, all windows had gold plating, and all wiring, piping and control runs were carefully sealed against radiation where they passed through the fuselage bulkheads. EMP measurements made at a later date confirmed the high efficacy of these precautions – the magnetic field levels in the flightdeck and the crew compartment did not exceed the prescribed limits.

The rotodome, which was almost entirely dielectric, was developed jointly by the engineers of the Antonov OKB and NPO Vega-M. Prototype examples underwent extensive static testing with a view to confirming the possibility of manufacturing large stressed structures with thin walls. The results were positive; during static tests one of the rotodome's three GRP shells withstood 300% of the design load and another one absorbed 230% before failing. Much effort was spent on designing and refining the rotodome's bearing and drive unit, as well as on the design of the radar antenna and the methods of tuning it; the tests involved both scale models and full-size articles.

Much importance was also attached to EMC. Between 1985 and 1990 NPO Vega-M developed a special automated EMC measurement system the likes of which had not been seen in the Soviet Union or abroad. This system significantly reduced the time needed for tests and enhanced measurement accuracy, making it possible to expand the scope of the tests; avionics modules could be tested in pairs or in larger groups. The Antonov OKB built a special test rig for this system and made appropriate modifications to the existing navigation and communications suite test rigs, allowing them to work together; this allowed avionics to be checked on the ground before installing them in the aircraft. Both

An-71 prototypes featured this system, and it proved its worth during the trials.

Fitted with a partial non-functional mission avionics suite, the first prototype was completed in mid-May 1985, wearing full Aeroflot livery and the non-standard registration CCCP-780151. The rollout ceremony at Kiev-Svyatoshino took place on 23rd June; the following day the aircraft was refuelled for the first time and calibrated.

Note: The unusual six-digit registrations encountered on some Antonov prototypes are usually explained as follows. The first and the last digits correspond to the aircraft type: in this case, 7****1 = An-71. By comparison, the second and third An-32 prototypes (c/ns 001 and 003) were initially registered CCCP-380122 and CCCP-380322; the An-74 prototype was originally CCCP-780334. (However, this does not work with all Antonov types; cf. An-22PZ CCCP-180151, An-124s CCCP-680125, CCCP-680345 and An-225 CCCP-480182!) The meaning of the second digit, which is always an 8, remains unknown; this may be a code for the OKB's experimental shop. The next two are the last two digits of the c/n (or, in this case, the full c/n). Finally, the last-but-one digit shows the year of manufacture; in this case, 5 = 1985.

The Protocol on the transfer of the aircraft to the flight test facility was signed on 3rd July. Two days later CCCP-780151 made the first high-speed runs, and the aircraft and its crew were declared ready to fly. On 11th July a panel composed of Antonov OKB, Air Force and LII representatives gave the formal go-ahead to perform the first flight. This took place the following day; the An-71 left the ground at 14.30 Moscow time, flown by a crew comprising captain A. V. Tkachenko, co-pilot S. A. Gorbik, flight engineer V. A. Petrenko and test engineer I. I. Radautsan. As was the case with all Kiev-built Antonov prototypes, the first flight was a short hop from Svyatoshino to Gostomel' in the north-western suburbs.

By the end of the year CCCP-780151 had made 75 test flights, logging a total of 117 hours; these included 50 flights under the so-called 'General Designer's programme' (that is, initial performance and handling tests) and 25 flights to verify and debug the aircraft's systems. In May 1986 the first prototype flew its first test mission with a functional 'Mk I' mission equipment suite installed shortly before.

A while earlier, on 25th June 1985, the first prototype An-71 had its first 'public outing' – albeit the 'public' was rather special, to say the least. A large government delegation from Moscow headed by the nation's new leader, Communist Part Central Committee Secretary General Mikhail S. Gorbachov, visited Kiev; the schedule of the trip included a visit to the Antonov OKB (KMZ) where the latest



Above and below: An-71 CCCP-780151 at Kiev-Svyatoshino during initial flight tests. Note the 'droopsnoot' radome and the air data boom attached to the starboard side of the fin and the double-hinged rudder with a kinked joint line between the upper and lower sections.





Above: An-71 CCCP-780151 makes a high-speed run at Klev-Gostomel'. The port and starboard sides of the main gear fairing have different shapes.
Below: The aircraft uses reverse thrust on landing. Note the strong dihedral of the stabilisers and the small depth of the rotodome.





Above: The famous photo that revealed the An-71's existence for the world to see. Antonov OKB General Designer Pyotr V. Balabuyev and the Soviet Union's leader Mikhail S. Gorbachov are second and third from left respectively. The other two aircraft are the An-72P prototype and An-72A CCCP-780334.

Antonov aircraft were lined up at Svyatoshino for the benefit of the guests. Somehow accidentally-on-purpose one of the press photographers took a picture of Gorbachov and his retinue at just the right moment so that the An-72P, An-72A (An-74) and An-71 prototypes were visible in the background. When the photos were circulated and the West got

its first glimpse of the An-71 with its distinctive forward-swept tail topped by a rotodome, the Western experts' first reaction must have been something like 'the crazy Russians have got the tail on backwards' and the aircraft was assigned the not-too-inappropriate reporting name *Madcap*. Curiously, in 1987 the famous photo found its way to a Soviet book devoted

to... Aeroflot Soviet Airlines. An AWACS aircraft in an Aeroflot publicity book... of all things!

Meanwhile, the second prototype An-71 was rolled out on 19th February 1986; like the first one, it sported a six-digit registration, CCCP-780361. The aircraft made its first flight on 28th February, piloted by captain G. Lysenko and co-pilot A. V. Tkachenko, with Yu. A. Dmitriyev as flight engineer and M. N. Berezyuk as test engineer. Upon completion of the 'General Designer's programme' both aircraft commenced manufacturer's flight tests.

In the summer of 1988 the An-71 was part of an aviation technology display arranged at Kubinka AB for 'the chosen few'. The display also featured prototypes of the Mikoyan MiG-29M tactical fighter and MiG-31M interceptor, the Sukhoi Su-27M tactical fighter, the Kamov V-80 (Ka-50) attack helicopter and the Tu-160 strategic missile carrier.

By the time the An-71 programme was suspended, the first prototype had logged 650 hours' total time in 387 flights, while the second aircraft had made 362 flights totalling 380 hours. Test crewmen came and went as the programme progressed, but project test pilot Sergey V. Maksimov shouldered the main part of it. The following parameters of the new AWACS were explored:

- the aircraft's behaviour at maximum speeds and G loads determined by the structural strength limits;



CCCP-780361, the second prototype An-71, at the aviation technology display at Kubinka AB in 1988, in company with an A-50 and a Tu-160 strategic missile carrier.



Above and below: An-71 CCCP-780361 at Kiev-Gostomeľ'. The stripes on the fin leading edge are for icing visualisation. Note the smaller tailcone, the differently shaped radome and the unpainted upper trailing-edge segment of the rudder.





A bird's eye perspective of the second prototype An-71. As this photo shows, the starboard stabiliser's leading edge was also zebra-striped for icing tests.

- handling with simulated control system malfunctions;

- stability and handling throughout the speed envelope, CG range and bank/sideslip angle range (this included the non-banked turn mode which is an important part of an AWACS aircraft's operational procedures);

- main and booster engine operation;
- operation of the aircraft's systems, including the ancillary systems of the mission avionics suite;

- the mission avionics suite's EMC with the Doppler speed/drift sensor and the long-range radio navigation system (both systems turned out to be suffering EMC problems, and the remedy was to install a shield around the Doppler sensor and relocate the LORAN strake aerials);

- the mission avionics suite's EMC with the communications suite;

- internal and external EMC;

- operation of the mission avionics suite's cooling system and the temperature inside the avionics bays;

- EMP sealing of the airframe and the efficacy of the flight and ground crew's EMP protection when the radar was in operation;

- operation of the communications suite in air-to-ground and air-to-air modes, including the electronic counter-countermeasures (ECCM) mode;

- operation of the search radar, including such parameters as detection range, the computing system's and antenna system's power consumption, the influence of the air-

frame on the field of view, the effect of background clutter and so on;

- the vibration characteristics of the mission avionics and other systems.

Generally the flight and navigation avionics suite met the design specifications, ensuring automatic navigation in all flight modes (take-off, flight to the patrol zone, on-station loiter with non-banked turns, return to base and landing). Thanks to the digital moving target selection function the radar could detect up to 400 targets over land or water and track up to 120 priority threats in track-while-scan mode, directing ships or interceptors to them if necessary. At an altitude of 8,000 m (26,250 ft) the An-71 could detect targets travelling at 100-30,000 m (330-98,425 ft) in any direction within a 370-km (230-mile) radius. The aircraft could loiter at this altitude for up to five hours, circling at 500-530 km/h (310-329 mph). Like the An-72 transport on which it was based, the An-71 could operate from grass/dirt strips as well as from paved runways.

The tests revealed inadequate efficiency of the rudder trim tab and poor longitudinal stability; these problems were addressed by increasing the thickness of the trim tab's trailing edge to 30 mm (1 1/8 in) and clipping the tips of the elevators. The electric trim tab controls periodically started 'acting up'; the cause was traced to induced signals generated by the equipment and ways were sought to eliminate them.

For the obligatory high-alpha tests An-71 CCCP-780151 was equipped with a spin

recovery parachute; the parachute canister built into the tailcone was provided with an upward-hinged ogival cover held in place by a ventral lock. In connection with this test programme the flightdeck was fitted with a special extractor system to facilitate bailing out. Special powered carriages with handles moved along tracks attached to panels on both sides of the passage from the flightdeck to the entry door. Should spin recovery become impossible, each crewman would grab hold of the handle on the carriage with both hands and activate a thumbswitch. The carriage would then move, dragging him forcibly out of his seat and propelling him towards the entry door, which was opened by a hydraulic ram; all he had to do was dive into the doorway and yank the rip cord.

The high-alpha tests proceeded in April 1988 and confirmed the anticipated control characteristics; at maximum angles of attack the An-71 showed no propensity to spin. Thus, fortunately the mechanical 'bouncer' remained unneeded.

As usually happens during trials, funny episodes occurred. The ground personnel was well aware that the high-frequency radiation of the powerful search radar could seriously damage your health if you were within a radius of several hundred metres of the aircraft. One day the An-71 was sitting on the hardstand at Gostomel' with the rotodome in motion (the drive had been switched on for test purposes). Knowing that operating the radar on the ground was strictly forbidden,



Above and below: These shots of CCCP-780361 landing at Vladimirovka AB illustrate well the asymmetrical shape of the wraparound main landing gear fairing whose starboard side incorporates the mission equipment's heat exchanger.





Above and below: Looking rather grubby and missing the landing lights and upper main gear door segments, but otherwise intact, the second prototype sits in Kiev-Svyatoshino during the third Aviasvit-XXI airshow in September 2002. Note the small 'YeS UVD' (United ATC System) titles on the cheatline.



the technicians working on other aircraft parked close at hand still eyed the machine suspiciously. Suddenly the An-71's entry door opened and two crewmen stepped out, clad in metal-coated radiation protection suits making them look like spacemen. Instantly realising the danger, the technicians ran hell-for-leather, trying to get out of harm's way. Within seconds the hardstand was empty. When the technicians realised they were the victims of a practical joke, the result was a frightful outpouring of... well, *technical language*.

In addition to the Kiev Region, the test flights took the An-71 prototypes to Central Asia (specifically, Chornaya Rechka, or Black River, test range near Tashkent), the Caucasus, the regions adjoining the Volga River and the Crimea Peninsula. Test flights were performed over varying types of terrain (from a background clutter standpoint) and in all seasons. Stage A of the manufacturer's flight tests was completed almost fully. According to the research establishments of MAP and the MoD, working in concert with the An-71 could boost the combat efficiency of fighter units by a factor of 2.5 to 3. Additionally, the aircraft could have civil uses as a flying air traffic control/relay station, controlling the air traffic above underdeveloped areas lacking in ATC infrastructure and directing search and rescue operations; thus the 'YeS UVD' (*Yednaya sistema upravleniya vozdooshnym dvizheniyem* – United, that is nationwide, ATC System) were not merely a misguided attempt to conceal the An-71's military nature. The aircraft and its systems did not require specialised ground support equipment and the machine could operate off-base for up to thirty days.

Unfortunately, the trials were never completed; the dissolution of the Soviet Union and the resulting political and economic chaos shattered all the plans involving the An-71, leaving the aircraft without a customer. With no further state funding available, the programme was mothballed and the two prototypes were placed in long-term storage at Kiev-Gostomel' and Kiev-Svyatoshino respectively. CCCP-780361 was readily accessible to the public and invariably aroused the visitors' interest during the biennial Aviasvit-XXI airshows.

The An-71 in Detail

Type: Tactical airborne early warning and control aircraft. The airframe is basically of all-metal riveted and bonded construction utilising high-strength aluminium alloys and honeycomb structures. The crew complement comprises two pilots, a flight engineer and three mission crew members.

Fuselage: Semi-monocoque stressed-skin structure of beam-and-stringer construction with frames. The fuselage cross-section is basically circular, changing to elliptical with the longer axis horizontal in the extreme nose (ahead of the flightdeck windshield) and in the rear fuselage. Maximum fuselage diameter is 3.1 m (10 ft 2 $\frac{3}{4}$ in).

Structurally the fuselage is made up of three sections: the forward fuselage, the centre fuselage and the rear fuselage. All three sections are joined by flanges. The structure is identical to that of the An-72 up to frame 23; the remainder is new. Part of the fuselage is pressurised.

The *forward fuselage (Section F1)* includes the flightdeck, which is separated from the mission crew compartment by a rigid bulkhead with a pressure door, and the foremost portion of the said compartment. The foremost frame is the kinked forward pressure bulkhead mounting the weather radar dish; the GRP radome of honeycomb construction with ten lightning protection strips opens upward and is secured by five Camloc tension locks. The nosewheel well is located immediately aft of the pressure bulkhead. It is flanked by two avionics bays below the flightdeck floor, with upward-opening carbonfibre reinforced plastic (CFRP) access covers on both sides; each cover is held in place by six Dzus fasteners.

The flightdeck glazing features a one-piece frame with two curved windshield panels and two side windows on each side; hydraulically-powered windshield wipers are provided. The foremost pair of side windows are sliding direct vision windows which can be used for emergency evacuation on the ground. There is also an inward-opening square-shaped escape hatch measuring 0.5 x 0.5 m (1 ft 7 $\frac{1}{8}$ in x 1 ft 7 $\frac{1}{8}$ in) in the flightdeck roof providing access to the upper surface of the aircraft for maintenance purposes. The windshield is made of birdproof triplex silicate glass and features electric de-icing; all other flightdeck windows have Perspex glazing. All windows have gold plating for protection against EMP.

A rectangular forward-hinged entry door measuring 0.9 x 1.65 m (2 ft 11 $\frac{1}{8}$ in x 5 ft 4 $\frac{3}{8}$ in) with a small circular window is located on the port side at the rear of Section F1; the door opens outward through 90° and may be actuated hydraulically to act as a slipstream deflector for bailing out. This necessitates the use of a detachable boarding ladder.

The *centre fuselage (Section F2)* is divided into three bays. Bay 1 accommodates the mission crew cabin with operator consoles to starboard and part of the mission and flight avionics modules to port and under the ceiling. The other two bays are avionics bays. Bay 2 accommodates more mission and flight

avionics. Bay 3 houses the radar set, the booster engine and its air intake assembly, the mission avionics' liquid cooling system and flight control system components. Bays 1 and 2 are separated by a metal bulkhead with a door, while bays 2 and 3 are separated by a wire mesh screen with a door. In order to isolate the delicate radar set from the vibrations of the fuselage the electronics modules are mounted on a special resilient platform which is hollow and incorporates air cooling system ducts. Part of the avionics and equipment is located under the floor.

Two fuselage mainframes serve as attachment points for the wing centre section's front and rear spars respectively. The wing/fuselage joint is enclosed by a fairing whose front and rear sections are made of GRP; apart from flap and slat drives, it houses some of the avionics.

A large flat-bottomed GRP fairing is located on the centre fuselage underside. It accommodates the main landing gear units (the mainwheel wells are separated by the fuselage keel beam), the APU (in the rear section on the starboard side) and various equipment items.

The upswept *rear fuselage (Section F3)* incorporates an orifice for the booster engine nozzle and terminates in a GRP tailcone; it also carries the tail unit.

Wings: Cantilever shoulder-mounted monoplane wings of basically trapezoidal planform, mounted above the fuselage to avoid encroaching on the freight hold. Leading-edge sweep 17° on the inner wing sections but reduced on the outer wings, anhedral 10° outboard of the engines, aspect ratio 11. The wings utilise TsAGI airfoils with a high lift/drag ratio throughout the aircraft's speed range.

The wings are all-metal stressed-skin structures made mostly of duralumin. Structurally they are made up of five pieces: the centre section permanently attached to the fuselage and detachable wing panels divided into inner and outer sections, plus GRP tip fairings. The inner wing panels have no sweepback on the trailing edges; the outer wings feature reduced leading-edge sweep and modest trailing-edge sweep resulting in kinked leading end trailing edges.

The large-span centre section carries the engine nacelles; titanium heat shields are provided on the upper surface aft of the engine nozzles on production aircraft. The wing/fuselage joint is covered by a fairing (see above) incorporating air conditioning system air intakes at the front and hinged dorsal access panels. The wing leading and trailing edge undersides feature numerous hinged panels made of CFRP for access to control runs, hydraulic lines, flap drive shafts, electric cables and so on.



Above: The nose of the second prototype An-71. The radome is identical to that of the production An-72/An-74 and features lightning protection strips. Note the ECM blister further aft.



The rear fuselage, tail unit/rotodome combo and booster engine nozzle of the second prototype. The dorsal bulge on the fin conceals the booster engine's closed air intake.

The wings are equipped with powerful high-lift devices – double-slotted flaps on the centre section, triple-slotted flaps on the inner wing sections and three-section leading-edge slats (one section on each inner wing section and two on each outer section). The flaps move on external tracks enclosed by GRP fairings (two on each inboard/outboard flap). The inboard flaps are set directly, the outer flaps and the LE slats moving in concert: the inboard/outboard flaps are powered by different hydraulic systems for greater reliability. Flap settings are 10° inboard/25° outboard for take-off and 60° inboard/40° outboard for landing.

Four-section electro-hydraulically actuated spoilers/lift dumpers are installed on each inner wing panel; the innermost pair acts as airbrakes and the outer two pairs are used for roll control. The spoilers also deploy on touchdown to shorten the landing run. Two-section ailerons (see Control system) are installed on the outer wings.

Tail Unit: Conventional tail unit of all-metal stressed-skin construction. The forward-swept vertical tail consists of a fin and a large double-hinged rudder (see Control system). The fin is a multi-spar stressed-skin structure with a one-piece detachable leading edge doubling as a de-icer. The fin leading edge is kinked at the root, the root portion featuring sweepback. The rudder segments are both split into upper and lower halves; the entire rudder deflects at low speeds but the upper half is locked neutral in cruise mode.

The vertical tail carries the rotodome and incorporates its drive unit. Only a small portion of the rotodome is a metal support structure; the rest is formed by GRP shells (front, rear and port/starboard) designated A1, A2 and A3.

The fixed-incidence horizontal tail of trapezoidal planform comprises two dihedral stabilisers and one-piece elevators (see Control system). It has an inverted airfoil with a flat upper surface. Leading-edge sweep 23°, no trailing-edge sweep. Each stabiliser is of two-spar construction.

Landing Gear: Hydraulically-retractable tri-cycle type, with free-fall extension in emergency. The nose unit features twin 720 x 310 mm (28.3 x 12.2 in) non-braking wheels and is fitted with a combined steering actuator/shimmy damper. The four independent main units have single 1,050 x 390 mm (41.3 x 15.3 in) wheels equipped with hydraulic multi-disc brakes. The wheels have identical dimensions to those of the An-72/An-74 but are of a different type.

All landing gear struts are made of titanium and have oleo-pneumatic shock absorbers and levered suspension. The steerable

unit can turn $\pm 50^\circ$ for taxiing and is controlled by a tiller on the port cockpit console. There are separate parking brake levers for the port and starboard wheels; these can be locked together.

The nose unit retracts forward, the main units inward into a large ventral GRP fairing which encloses both the mainwheel wells, the main gear fulcrum (main pivot) attachment fittings and the actuation gear. The main gear struts have breaker struts retaining them in extended position but no uplocks, the mainwheels resting against the inner faces of the mainwheel well doors when retracted. Maximum landing gear transition speed is 345 km/h (214 mph).

The nosewheel well is closed by two lateral doors and a small rear door segment hinged to the oleo strut. The main units on each side have a large common main door attached to the fuselage keel beam, closing the wheel well, and small individual doors hinged to the oleos. All wheel well doors are made of CFRP; the larger doors open only when the gear is in transit.

Powerplant: The cruise engines are two Muravchenko (ZMKB Progress) D-436T1 turbofans with a take-off thrust of 7,500 kgp (16,530 lbf) in standard atmosphere conditions and 1,500 kgp (3,310 lbf) for cruise at 11,000 m (36,090 ft) and Mach 0.75. The engine is manufactured by the Zaporozhye Engine Factory (ZMZ, later Motor-Sich). It has a modular construction of 12 basic sub-assemblies which can be replaced in service; and makes large-scale use of titanium.

The D-436 is a three-spool turbofan with a single-stage transonic fan having 29 titanium blades with part-span shrouds (snubbers) and a parabolic spinner, a six-stage transonic low-pressure (LP) axial compressor featuring fixed inlet guide vanes, titanium discs/rotor blades, steel stator vanes, a seven-stage subsonic high-pressure (HP) axial compressor with variable inlet guide vanes, bleed valves at the 3rd and 4th stages, titanium blades on the first five stages and steel blades elsewhere, a low-smoke annular combustion chamber with 24 fuel nozzles and two igniters, single-stage HP and LP turbines with cooled blades, and a three-stage fan turbine. Each spool rotates in two bearings – that is, there are only six bearings (no inter-shaft bearings).

There are separate core and bypass nozzles (called rear support case and bypass duct respectively). The bypass duct is split into front and rear modules (called contravane case and intermediate case respectively). The contravane case features 49 stator blades and is reinforced with a composite liner to preclude uncontained fan failure; the fan blades are designed to withstand birdstrikes.

A ventral accessory gearbox is mounted on the intermediate case. Starting is by means of an SV-36 air turbine starter (*startyor vozdooshnyy*) using compressed air from the APU, ground supply or cross-feed from the other engine.

Bypass ratio 4.98, overall engine pressure ratio at take-off power 22.17, cruise SFC 0.617 kg/kgp·h, turbine temperature 1,520°K, dry weight 1,450 kg (3,200 lb). Length overall 3,470 mm (11 ft 4 $\frac{3}{4}$ in), width 1,541 mm (5 ft 0 $\frac{1}{2}$ in), height 1,711 mm (5 ft 7 $\frac{3}{4}$ in); dry weight 1,106 kg (2,438 lb).

The D-436 has a self-contained pressure-feed lubrication system, as well as a fuel flow control system and an electronic engine control system ensuring automatic starting and stable operation in all modes. The fuel flow control system maintains constant engine rpm in accordance with the throttle settings. The electronic engine control system monitors the engines' operating parameters (exhaust gas temperature, vibration levels and so on) and automatically throttles back the affected engine if any of these parameters reaches a dangerous level or the engine surges. Apart from manual control by the pilots, engine rpm may be set automatically by the SAU-72 automatic flight control system which includes an autothrottle.

The engines are mounted in nacelles attached to the wing centre section above and ahead of the wing leading edge and are carried in truss-type bearers; the engine attachment lugs are mounted on the bypass duct and the rear support case. Each nacelle consists of a one-piece annular forward fairing incorporating a de-icer, three pairs of double cowling panels (two of these panels form work platforms on either side of the engine), two large cowling panels hinged at the top and a fixed rear portion. The latter incorporates a thrust reverser which is part of the air-

frame, not the engine, and serves both the core flow and the bypass flow for maximum effect. Each thrust reverser has an aft-hinged main door and an internal blocker door aft of it which drops down against the wing's upper surface; together they direct the exhaust flow forward and up. The exhaust orifices have a flattened shape to spread the jet over the inboard flaps. The nacelles' forward portions and cowlings are made of GRP.

A Kolesov (RKBM) RD-36A booster turbojet rated at 2,750 kgp (6,060 lbf) for take-off is installed in the rear fuselage. The dorsally positioned air intake is closed by an aft-hinged door in a flattened teardrop fairing and provided with an S-duct; the nozzle is buried in the rear fuselage underside.

A Stoipino Machinery Design Bureau TA-12 APU is provided for self-contained engine starting, ground power supply and air conditioning. The TA-12 has a four-stage axial compressor, a three-stage axial turbine, a GS-12TO DC starter/generator and a 40-kW GT40PCh8B stable-frequency AC generator. Dimensions, 1.588 x 0.682 x 0.721 m (5 ft 2 $\frac{1}{2}$ in x 2 ft 2 $\frac{5}{8}$ in x 2 ft 4 $\frac{3}{4}$ in), dry weight less generators 290 kg (640 lb). Bleed air pressure 4.9 bars (70 psi), delivery rate 1.6 kg/sec (3.52 lb/sec), equivalent power 287 kW, fuel consumption 250 kg/h (551 lb/h). The APU can be started at altitudes up to 7,000 m (22,965 ft). It is installed in the starboard rear portion of the main gear fairing under a one-piece upward-hinged CFRP cowling, featuring an upward-opening aft-hinged dorsal intake door and a lateral exhaust surrounded by a steel heat shield. It is started, using 27V DC from a ground source or on-board DC batteries.

Control System: Powered dual flight controls with irreversible hydraulic actuators in all three control circuits and a manual emergency backup mode. Control inputs are



Another view of the rotodome. The darker grey portion is the support structure made of aluminium alloy. Note that the largest dielectric sector, forming nearly half of the rotodome, is built in four portions.

transmitted to the actuators by conventional mechanical linkages (push-pull rods, cranks and levers).

Roll control is provided by two-section ailerons on the outer wings assisted by the outer two spoiler sections on each wing; the spoilers come into action when the control wheel angle exceeds 15°. The smaller inboard aileron sections are controlled directly and used in high-speed flight; the outer sections join in at low speeds. In the event of an engine failure with more than 10° flap the outermost spoiler section on the live-engine side is deployed automatically to offset the lift asymmetry caused by the thrust asymmetry; ten seconds later it sinks back over another ten seconds, giving the pilot time to react. Each aileron section is hinged on two brackets. The inboard sections have geared tabs; the port inboard aileron also has an electrically operated trim tab.

Pitch control is provided by one-piece elevators with both aerodynamic balancing (horn balances) and mass balancing. Each elevator is hinged on four brackets and incorporates a geared tab and a trim tab. Additionally, the aircraft is balanced fore and aft by changing the tailplane incidence.

Directional control is provided by a double-hinged rudder whose forward and rear segments are split into upper and lower halves; each rudder segment is carried on three brackets. The upper and lower sections are powered by separate actuators; the lower rear section features a trim tab at the root. The forward rudder segment hinged to the fin torsion box deflects automatically to offset the thrust asymmetry in the event of an engine failure. In take-off and landing mode the travel of the lower forward rudder segment is limited and the upper forward segment is locked neutral. Both forward sections are mechanically linked to the lower rear section and are linked to an ADR-87 automatic yaw damper (*avtomaticheskii dempfer ryskan'ya*).

The aircraft has an SAU-72 automatic control system including an autopilot; the system's directional control channel operates as a yaw damper. The autopilot servos are connected to the control runs in parallel and may be disengaged pyrotechnically if they jam. The servos feature overriding clutches, allowing the pilots to take corrective action when the autopilot is engaged.

Electrically-actuated gust locks are provided to prevent damage to the control system by high winds while the aircraft is parked. The rudder and ailerons are locked neutral and the elevators fully down to offload the hydraulic actuator. For safety reasons, throttle movement is mechanically limited if the gust locks are engaged; the locks are inhibited with the landing gear in no-load position.

Fuel System: The wing torsion box (centre section, inner and outer wings) is divided into seven integral fuel tanks. Total fuel capacity is 16,250 litres (3,575 Imp gal). The fuel tanks are split into four groups (Zero, One, Two and Three); the Group Three tanks are service tank (to be precise, each of them features a service section from which fuel is fed to the respective engine). The Group Zero tank holding 2,395 litres (526.9 Imp gal) is a reserve tank filled for long-range flights only.

Normally the port and starboard halves of the system are isolated, but a cross-feed valve enables each engine to draw fuel from any group of tanks. The APU is fed from the port engine's fuel line or by a special APU supply pump installed in the starboard Group Three tank.

The An-71 has single-point pressure refuelling; the refuelling panel is located on the port main gear fairing between the main gear units. Refuelling to maximum capacity at 4.5 kg/cm² (64 psi) takes about ten minutes. Fuel grades used are Russian T-1, TS-1 or RT kerosene or equivalent; the addition of water crystallisation inhibitors (grade 'I' special fluid or tetrahydrofurfural alcohol) in winter enables refuelling at ambient temperatures of +5°C (+41°F) or lower. The refuelling and fuel usage sequence is controlled automatically by the fuel metering/control system or manually by the crew.

A vent system is provided; venting is done via the Group Zero tank which is connected both with all other tanks and with the atmosphere. Fuel jettisoning in flight is possible via the engines' fuel delivery lines by means of jettison cocks located on the starboard side of both engine nacelles, using the transfer pumps and delivery pumps. Defuelling is possible via the drain valves found in each tank.

Hydraulics: Two separate hydraulic systems (port and starboard) which power the control surface actuators, high-lift devices, spoilers, landing gear, nosewheel steering mechanism, wheel brakes, thrust reversers, entry door emergency actuator and windshield wipers.

Both systems use AMG-10 oil-type hydraulic fluid. Both systems are powered by variable-capacity engine-driven pumps. Each system has its own hydraulic tank; the two tanks are manufactured as a single module and equipped with a pressurisation system.

The port hydraulic system includes an electrically-powered pump unit and a hand-driven pump as back-up hydraulic power sources. The electric pump unit ensures the operation of hydraulic equipment on the ground during maintenance and tops up the parking brake's hydraulic accumulator.

A cross-feed valve allows the engine-driven pumps and electric pump unit to serve

all hydraulically powered equipment; if one pump fails, the other pump can serve both systems, providing there is no hydraulic leak.

Electrics: The electric system operates the avionics, part of the de-icing system and fuel system components (pumps and cocks). Primary 200/115V/400 Hz three-phase AC is supplied by four GP-23 engine-driven generators or a generator driven by the APU. Total primary power is 240-kVA. Secondary power sources are two 2-kVA step-down transformers providing 36V/400 Hz three-phase AC and two 6-kW rectifiers providing 27V DC.

All systems operate in parallel, each using its own group of distribution buses. Electric power management is automated; if a power source fails, its distribution buses are automatically switched to one of the surviving power sources. Overload protection devices automatically exclude a failed power source or damaged section of circuitry.

Three 27V (25 A-h) DC batteries are housed in the port rear portion of the main gear fairing and accessed via an upward-hinged CFRP cover. Backup three-phase AC power is provided by a 0.8-kVA static converter fed by the batteries. A 27V DC ground power receptacle is installed in the starboard front portion of the main gear fairing.

De-icing System: The de-icing system ensures icing protection at ambient temperatures down to -30°C (-22°F). The wing and tail unit leading edges and fuel tank venting system air intakes are de-iced by hot air from the air conditioning system; the engine air intakes are de-iced by hot air bled from the third HP compressor stage. Electric de-icing on the flightdeck windshield, pitot heads and static ports; the windshield is provided with wipers for removing the snow and melting ice. Alcohol de-icing on the flightdeck windshield.

A radioactive isotope icing detector is installed on the forward fuselage. The system is activated either automatically by the icing detector or manually but can be deactivated only manually.

Fire Suppression System: Two single-shot fire extinguisher bottles charged with 114V₂ grade chlorofluorocarbon are provided for fighting fires in the engine nacelles and in the APU bay. The crew is alerted by a fire warning system with flame sensors and an engine overheating warning system. The fire suppression system has a two-stage operating algorithm; the first shot is triggered automatically by flame sensors or manually at the discretion of the crew, the second shot manually only.

The fire extinguishers are triggered electrically from the overhead circuit breaker panel in the flightdeck. Two impact sensors

installed under the fuselage trigger all fire extinguishers automatically in a wheels-up landing. Portable fire extinguishers charged with 115V grade CFC are provided for fighting cabin and flightdeck fires, including electrical equipment fires.

To maximise fire resistance the airframe incorporates firewalls and fireproof materials. Systems and equipment are carefully laid out to minimise the fire hazard and drains are provided at locations where flammable liquids might accumulate.

Air Conditioning & Pressurisation System:

The flightdeck and cabin are pressurised and air-conditioned by air bled from the engines' 4th HP compressor stages in all operational modes, including ground idle, or the APU. There are two air conditioning systems (port and starboard) serving the cabin and the flightdeck respectively.

Cabin air pressure and temperature are maintained automatically or may be set manually. Maximum cabin pressure differential 0.49 kg/cm² (7.1 psi). Warning lights are provided for monitoring the systems' operation.

Pneumatic System: A separate system is provided for pressurising the avionics bays, air-cooling the electronics and adjusting tyre pressure, to suit the aircraft's weight and runway class (to facilitate operations from unpaved airstrips). The air is bled from the air conditioning system.

Oxygen system: An oxygen system is provided to protect the crew in the event of decompression or against smoke and toxic fumes in the event of a fire. The system comprises two 10-litre (2.2 Imp gal) oxygen bottles for the cabin, with distribution manifolds and connectors for individual oxygen masks, and stationary breathing apparatus for the flight crew. Operation time at least 3 hours for decompression and at least 15 minutes for smoke protection.

Liquid Cooling System: A liquid cooling system is provided for some of the avionics. The heat exchanger is located in the starboard forward portion of the main gear fairing. The NACA air intake features a hinged flow adjustment flap; the air outlet is located laterally ahead of the starboard main gear units.

Avionics and Equipment: The An-71 is fully equipped for all-weather day/night operation, including automatic and semi-automatic flight assisted by an autopilot. Special attention was paid to flightdeck ergonomics in order to reduce the crew workload.

Navigation and piloting equipment: SAU-72 automatic flight control/landing system comprising an autopilot and a Mal'va Doppler-based automatic navigation system. The SAU-72 permits automatic ICAO Cat I blind approach and landing (decision altitude 60 m/200 ft, horizontal visibility 800 m/2,600 ft). A navigation/weather radar is installed in

the nose, with separate navigation and weather displays. The flight avionics include a multi-channel speed and altitude data system, a metre-waveband long-range radio navigation system, a decimetre-waveband short-range radio navigation system and distance measuring equipment. An I-21 inertial navigation system is provided, linked to the navigation computer and the LORAN system.

Communications equipment: HF communications/command link radios for long-range air/ground communications. Short-range VHF air/air and air/ground communications radios with AShS-UD blade aerials on the forward fuselage underside and atop the starboard engine nacelle. An emergency radio is fitted to assist in locating the aircraft in the event of an off-field forced landing in localities lacking ground nav aids. An intercom is also provided.

Mission avionics: The An-71 is equipped with an early warning and control suite built around a pulse-Doppler search radar with a 360° field of view developed by NPO Vega-M; a digital data processing system; a radar data presentation system with operators' consoles; an IFF interrogation system; a command link system for communicating target data to 'friendly' fighters or ground and ship-board C³I centres; encoding and decoding equipment; and a data recording system.

IFF system: SRO-1P Parol'-2D (izdelye 62-01) IFF transponder with characteristic triangular aerials located on the flightdeck roof



A rear view of the second prototype An-71, showing the booster engine nozzle. Note the soot deposits on the wings' upper surface aft of the engine nozzles.

An-71 specifications

Length overall	23.5 m (77 ft 1 $\frac{3}{4}$ in)
Wing span	31.9 m (104 ft 7 $\frac{3}{4}$ in)
Height on ground	9.2 m (30 ft 2 $\frac{3}{4}$ in)
Maximum speed, km/h (mph)	650 (403)
Service ceiling, m (ft)	9,500-10,800 (31,170-35,430)
Required runway length (paved/unpaved), m (ft)	1,400/1,800 (4,590/5,900)
On-station loiter speed, km/h (mph)	500-530 (310-329)
On-station loiter altitude, m (ft)	8,000 (26,250)
On-station loiter time with 1-hour fuel reserves, hours	4.5-5.0
Overland coverage, km (miles):	
against fighter-type targets	350 (217)
against targets with $\approx 2\text{-m}^2$ (21.5 sq ft) radar cross-section	200 (124)
Coverage:	
in azimuth, degrees	360°
in altitude, m (ft)	100-30,000 (330-98,425)
360° scan time, seconds	10
Number of targets tracked at \approx time	120
Planar co-ordinate measurement accuracy, km (miles)	2.5 (1.5)
Ground clutter suppression, dB	50-60

and the tailcone (just aft of the rudder trailing edge).

The aircraft also features ATC transponders enabling flights in and outside the CIS. These transmit the aircraft's registration, speed and altitude for presentation on ATC

radar displays and may operate in 'Mayday' mode.

Data recording equipment: MSRP-64-2 or MSRP-64M-2 flight data recorder and Mars-BM cockpit voice recorder. The FDR captures 12 parameters, including barometric altitude,

indicated airspeed, roll rates, vertical and lateral G forces, control surface deflection and throttle settings, as well as gear/flap transition etc. All recorders have armoured shells to ensure survival in a crash.

Lighting equipment: Port (red) and starboard (green) navigation lights at the wingtips, white tail navigation light on the end tailcone. Retractable PRF-4M landing/taxi lights on the sides of the main landing gear fairing at the front. White MSL-3 rotating anti-collision beacons under the main landing gear fairing, offset to port, and on top of the rotodome. Tail unit inspection light buried in the rear fuselage near inspection window to enable icing checks to be made. Primary and back-up cabin, flightdeck and instrument panel lighting.

Antonov An-75 AWACS Aircraft (Project)

As noted earlier, in the early 1980s the Antonov OKB undertook research and development work on a shipboard AWACS aircraft provisionally designated An-75. Apart from an adaptation of the existing An-71 project, an all-new design was also under consideration, although no details are available on the latter project.



An air-to-air of the first prototype at a late stage of the trials – also with 'YeS UVD' titles (just visible beneath the port engine nacelle).

The Naval Team

Yakovlev Yak-44E Shipboard AEW Aircraft (Project)

As noted in the preceding chapter, the Yak-44E project owes its inception to the ambitious CTOL aircraft carrier construction programme which had been pursued by the USSR since the mid-1960s. It was fairly obvious that operations of carrier-borne combat jets would not be effective unless they were backed up by adequate and timely information about the adversary forces in operational areas. This information could be provided only by a shipboard airborne early warning aircraft.

The Yakovlev OKB was tasked with the development of such a machine as early as 1979. In addition to the baseline AEW version, Yak-44 variants for other roles, including anti-submarine warfare (ASW), were to be developed in due course of time. By November 1979 the OKB submitted a technical proposal envisaging two alternative types of mission

equipment for the Yak-44E. The first of them, dubbed *Fakel* (Torch), comprised two radar antennas housed inside the fuselage and accommodated respectively in the fuselage nose and tailcone. The other option, called E-700, featured a radar antenna housed in a rotodome mounted on a pylon above the fuselage. Initially the go-ahead for further development was given to the *Fakel*-equipped version of the Yak-44E; its powerplant was to comprise two turboprops in underwing nacelles for cruise and four lift engines in the fuselage, to be used for STOL carrier-deck operations. However, placing the lift engines in the fuselage made it very difficult to provide enough space for the mission avionics. Difficulties encountered in the projecting of the *Fakel* radar system itself brought this work to a standstill, putting the Yak-44E project as a whole in jeopardy.

Concurrently, as noted in Chapter 3, the Antonov OKB was seeking to adapt its An-71 AWACS (conceived as a shore-based aircraft) for naval use, but eventually the Navy decided that the size and weight of the An-71 made it unsuitable for carrier-borne operations. As a result, the Yakovlev OKB was called upon to resume work on the Yak-44E, this time on the basis of a new concept dispensing with the lift engines. The new version of the Yak-44E was to be powered by two D-27 propfan engines and equipped with the E-700 AEW mission suite, featuring a conventional rotodome above the fuselage.

The Yak-44E was an AEW and airborne command post aircraft; its mission included monitoring the airspace and surface situation in designated areas, supplying information about the adversary's actions and target designation for combat aircraft. In its general



Close-up of the midships section of a model of the projected nuclear-powered aircraft carrier SNS *Ul'yanovsk* (Project 1143.7). A Yak-44 is about to launch from the waist catapult with the blast deflector shield erected; a second Yak-44E with the wings folded is sandwiched between parked Sukhoi Su-33 fighters.



Above: A full-scale mock-up of the Yak-44E with the wings unfolded and the rotodome elevated. Note the D-27 contraprops, the winglets and the mission equipment heat exchanger's air intake.



The same mock-up aboard the aircraft carrier SNS Fleet Admiral Kuznetsov with the wings folded and the rotodome lowered for below-deck stowage; note the aft-retracting main gear units and the feathered blades in the starboard prop's row. These photos make an interesting comparison with the E-2C on page 4.

configuration this shoulder-wing aircraft closely followed the Northrop Grumman E-2C Hawkeye; however, it was by no means a straight 'copy', incorporating some different design features. Unlike the E-2, whose rotodome was supported by a tripod-like structure and could be lowered 0.6 m (1 ft 11 in) to reduce the aircraft's height for below-deck stowage, the Yak-44's rotodome was mounted on a single pylon and could be lowered by more than 1.8 m (5 ft 10 in). There were only two vertical tails with double-hinged rudders (the Hawkeye had additional dorsal 'half-fins' at about half-span of each stabiliser, and all four fins featured rudders). The Yak-44 had unswept wings of high aspect ratio equipped with winglets (a feature absent on the E-2) and high-lift flaps and slats. The wing panels outboard of the engines folded upwards about skewed hinges, intersecting when folded; in contrast, the E-2's wings folded aft, rotating nose-down in the process.

The powerplant comprised two Muravchenko D-27 propfans designed by ZMKB 'Progress' (*Zaporozhskoye motorno-konstruktor'skoye byuro* – 'Progress' Zaporozh'ye Engine Design Bureau); D-227s are also mentioned in some sources. The engines were rated at 14,000 eshp (10,290 kW), driving Aerosila SV-27 contraprops of 4.49 m (14 ft 8 in) diameter. The front and rear rows had eight and six scimitar-shaped blades respectively, running at different speeds to reduce noise and vibration. Thus, being only marginally bigger than the Hawkeye, the Yak-44 had 2.5 times the engine power. Accordingly, it had almost twice the weight and a far greater fuel capacity.

The mission equipment included a powerful pulse-Doppler search radar developed by NPO Vega-M. In its characteristics it was expected to be considerably superior to the Westinghouse AN/APS-138 radar installed on the E-2C. The heat exchanger for the radar set was served by a ram air inlet ahead of the wings, just like on the Hawkeye. The aircraft featured a fly-by-wire flight control system. The pressurised fuselage provided accommodation for a crew of five with a high degree of comfort for long-duration flights (a toilet, a galley and a rest area with bunks were provided). The tricycle undercarriage had a track of 7.929 m (26 ft) and a wheelbase of 9.373 m (30 ft 9 in); unlike the E-2, the main units had twin wheels and retracted aft. The airframe would be fully ice-protected, with pneumatic de-icer boots on the tail surfaces and hot air de-icing on the wings, and stressed for catapult launch. At the same time the aircraft was suitable also for take-offs from the ski-jump deck incorporated on the Russian Navy's first (and so far only) CTOL carrier.

The Yak-44E was intended to enter Soviet Navy service for operations from *Kuznetsov*

class aircraft carriers. More exactly, it was to be stationed on board the carriers *Fleet Admiral Kuznetsov* and *Ul'yanovsk*, both officially termed heavy aircraft-carrying cruisers.

The former ship (Project 1143.5) was a non-nuclear carrier intended originally for catapult launching of aircraft but completed without deck catapults (with only a ski-jump at the bows for fighter take-offs). The ship was laid down in 1982 and launched as the *SNS Leonid I. Brezhnev*; she was later renamed *SNS Tbilisi* and bore this name during the tests before finally entering service with the Navy of a different state – the Russian Federation – as the *RNS Fleet Admiral Kuznetsov*.

The *SNS Ul'yanovsk* (project 1143.7) was to be the first Soviet fully-fledged CTOL aircraft carrier with a nuclear powerplant; for the first time it was going to be fitted with deck catapults for launching aircraft. On 4th October 1988 the as-yet non-existent ship was officially included into the inventory of the Soviet Navy. Construction started on 25th November 1988 at the Black Sea Shipyard in Nikolayev, the Ukraine, where all the other Soviet aircraft carriers had been built. However, on 1st November 1991, when the ship was 20% complete, construction was discontinued and the ship was excluded from the inventory; on 4th February 1992 she was broken up.

An advanced development project of the new version of the Yak-44E was completed by September 1988. It was officially endorsed by an appropriate directive of the Communist Party Central Committee and the USSR Council of Ministers in January 1989; the document also called for the development of other carrier-based derivatives of the Yak-44E. The aircraft was also intended for introduction into Air Force service.

In June 1989 the Yakovlev OKB commenced detail design of the Yak-44E; a full-scale mock-up was built and submitted to the mock-up review commission in January 1990. However, further work on the project was seriously hampered by turmoil following the collapse of the Soviet Union and the ensuing drastically reduced funding. In 1992, following a decision to cancel the construction of the aircraft carrier *Ul'yanovsk*, the work on the project was terminated at a stage when preparations were in hand for the construction of a prototype.

For some time the Yakovlev OKB kept the project afloat and continued at least until 1995 to promote the aircraft in the export market. These efforts failed to bring tangible results, nor did expectations of a renewed interest from the Russian Navy materialise. In the opinion of Russian specialists, the Yak-44E project, despite a considerable lapse of time since then, retains its value and competitiveness; if need be, it can be resurrected to meet present-day requirements.

Design specifications for the Yak-44E AEW aircraft

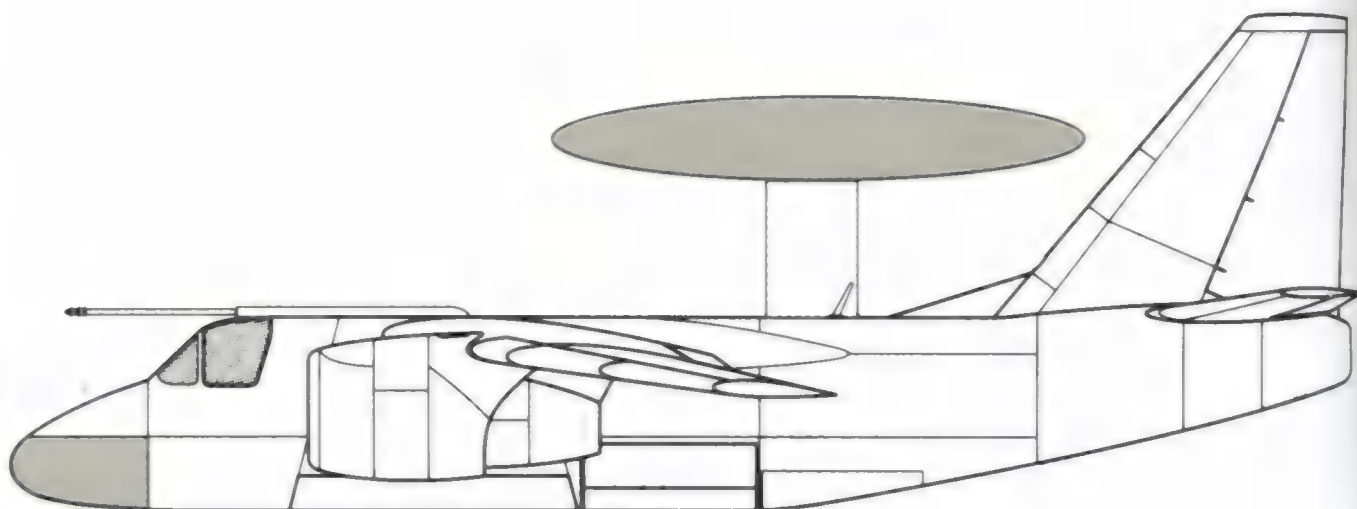
Length	20.39 m (65 ft 10 in)
Wing span	25.7 m (84 ft 3 in)
All-up weight, kg (lb)	40,000 (88,180)
Maximum speed, km/h (mph)	740 (460)
Service ceiling, m (ft)	13,000 (42,650)
Ferry range, km (miles)	4,000 (2,486)
Runway length for free take-off, m (ft)	1,300 (4,265)

Beriye P-42 Shipboard AEW Aircraft (Project)

In 1971, when the Soviet Navy started taking its first practical steps under the above-mentioned CTOL carrier construction programme, the Beriyev OKB – then known in unclassified correspondence as TMZ (*Taganrogskiy mashinostroitel'nyy zavod* – the Taganrog Machinery Plant) and headed by A. K. Konstantinov – was tasked with developing a shipboard ASW aircraft provisionally designated P-42. The programme, which was codenamed *Garpoon* (Harpoon), was kicked off by Council of Ministers directive No. 138 of 5th June 1971 and MAP order No. 177 of 24th June. The aircraft was to operate from Project 1160 carriers roughly equivalent to the USS *Nimitz* (the programme was codenamed *Oryol*, Eagle).

Although the Beriyev OKB had specialised in naval aircraft ever since its inception, it was breaking new ground with the P-42, as its previous aircraft had been seaplanes. Never before had the OKB's engineers had to cope with such requirements as deck launch by steam catapult, arrestor hook/arrestor wire systems, wing folding and all the other goodies characteristic of a shipboard CTOL aircraft.

Preliminary design studies resulted in an aircraft that bore a striking resemblance to the Lockheed S-3 Viking shipboard ASW aircraft – a high-wing monoplane with moderately swept high aspect ratio wings featuring marked anhedral and conventional swept tail surfaces with dihedral tailplanes. The aircraft was to be powered by two high-bypass turbofans – either an unspecified engine rated at 5,500 kgp (11,460 lbf), which in the event never materialised, or the 6,450-kgp (14,220-lbf) Lotarev D-36 – in underwing nacelles. Unlike the S-3, the engines were not pylon-mounted, the nacelles being mounted ahead of the wing leading edge so that their lower rear portions adhered directly to the wing underside. The twin-wheel nose unit and the single-wheel main units retracted aft into the fuselage. The flightdeck seated two pilots side by side and a mission equipment operator further aft; all crewmembers sat on ejection seats. The centre fuselage underside was



This is how the AWACS version of the Beriyev P-42 ■■■ to have looked. Note how the engine nacelles mate with the inner wings.

occupied by an interchangeable weapons bay allowing the aircraft to be configured for specific missions, with a sonobuoy bay further aft, and a telescopic magnetic anomaly detector (MAD) boom protruded from the tail-cone. A probe-and-drogue IFR system was provided, the probe being mounted on the centreline above the flightdeck roof.

Like its US counterpart, the P-42 was envisaged as a whole family of specialised versions. These included a refuelling tanker equivalent to the KS-3A, a search and rescue version, a COD version equivalent to the US-3A – and a shipboard AWACS. The radar, which was probably the same as envisaged for the Yak-44 described above, was again mounted in a conventional rotodome on a single centreline pylon (which was rigid, not telescopic). Because of the baseline version's wing folding arrangement the rotodome was located unusually close to the tail surfaces.

However, the CTOL carrier construction programme and hence the P-42 fell victim to politics – or, more exactly, internal strife and lobbying in the Soviet MoD. It so happened the then-Minister of Defence Marshal Andrey A. Grechko and the then-Minister of Shipbuilding Boris Ye. Bootoma, the main proponents of the programme, both passed away in 1976. After Grechko's death, Marshal Dmitriy F. Ustinov, who was opposed to the CTOL carrier programme for some reason, became the new Minister of Defence – and the programme immediately found itself in a stiff headwind. Try as he would, the then Commander-in-Chief of the Soviet Navy Fleet Admiral Gorshkov could not cope with Ustinov alone. Later, when Ustinov, too, died in

1982, the tide turned again for the CTOL carrier programme, but it was too late for the P-42.

Design specifications for the P-42 AEW version

Length	20.0 m (65 ft 7 $\frac{1}{2}$ in)
Wing span:	
wings deployed	25.3 m (83 ft 0 in)
wings folded	12.0 m (39 ft 4 $\frac{1}{2}$ in)
Height on ground	7.5 m (24 ft 7 $\frac{1}{2}$ in)
Wing area, m ² (sq ft)	82.0 (881.7)

Kamov Ka-31 Shipboard AEW Helicopter

From the outset the Moscow-based OKB-978 design bureau headed by Nikolay Il'yich Kamov specialised in helicopters using the co-axial layout (with contra-rotating rotors). Most of them were dedicated naval machines; the compact dimensions made possible by the co-axial layout rendered Kamov helicopters eminently suitable for shipboard operations. The company's first dedicated military model (and its first turbine-engined helicopter) was the Ka-25 anti-submarine warfare (ASW) helicopter which entered service in 1966. However, this machine was inferior to Western types on many counts, especially as regards range; furthermore, its operational reliability left a lot to be desired.

Hence in 1968 OKB-978 started work on a new shipboard ASW helicopter provisionally designated Ka-252 (that is, 'Ka-25 Mk II'). Retaining the predecessor's general arrangement with twin engines ahead of the gearbox, twin fins and rudders and a quad landing

gear, the Ka-252 featured a roomier fuselage, a new powerplant comprising two Izotov TV3-117VM turboshafts (giving 1.7 times the aggregate engine power as compared to the Ka-25's Glushenkov GTD-3s) and an Ivchenko AI-8V auxiliary power unit, new rotors with GRP blades, greater fuel tankage and enhanced avionics.

Development was sanctioned by Council of Ministers directive No.231-86 of 3rd April 1972. The work proceeded at a fast rate, and the first prototype made the first hover on 8th August 1973 and the first free flight on 24th December that year. After lengthy testing and refining the helicopter was included into the Naval Air Arm inventory under the service designation Ka-27 in April 1981, being produced by the Kumertau Aircraft Production Enterprise (KumAPP) in Bashkiria in ASW (Ka-27PL – *protivolodochnyy*) and search and rescue (Ka-27PS – *poiskovo-spasatel'nyy*) versions. A commercial version differing mainly in avionics and equipment emerged as the Ka-32. Later, a further naval version was brought out as the Ka-29 assault/transport helicopter (or Ka-29TB – *tranzportno-boyevoy*, transport/combat, used attributively). Intended as an armed support aircraft for the Marines, this helicopter introduced major structural changes – the cockpit was heavily protected by armour and flat bulletproof glazing panels replacing the earlier curved windshield and sliding side doors with blister windows. As a result, the cockpit section was 500 mm (1 ft 7 $\frac{1}{2}$ in) wider than the rest of the fuselage. Access to the cockpit was via a horizontally split door aft of it to starboard, the lower half incorporating boarding steps.



Above: ■ Ka-31 totally devoid of markings is pictured during a test flight with the landing gear retracted and the radar antenna deployed. Note the sliding windowless cabin door, the cockpit escape doors and the APU housing and jetpipe.



The first prototype Ka-31, '031 Blue', seen as the radar antenna tilts slowly into the vertical position to enable rotation. Note the retaining grips on the starboard side of the fuselage securing the front and rear ends of the antenna in the stowed position. The first prototype has red anti-collision lights.



Above: The second prototype, '032 Blue', passes over a tanker as it flies over the Black Sea off Novorossiysk. The helicopter is in its initial quasi-civil guise. Below: The same machine with an air data boom on the nose. Note the exposed equipment modules under the tailboom found only on this aircraft.





Above: '032 Blue' at a later date in full military markings. Note the boxy housing aft of the starboard main gear unit and the white anti-collision lights.
 Below: The same aircraft, still with 'Aeroflot/Ghidromettsentr' titles and Soviet flag, during an open doors day at the 929th State Flight Test Centre in Akhtobinsk in 1995.





Two more views of the same helicopter, now coded '32 Blue' but still sporting the air data boom on the nose, with the radar antenna stowed (above) and in mid-deployment (below). Note the raked aft end of the equipment housing on the starboard side; the second prototype was the only Ka-31 to have this housing.





Above and below: '032 Blue' in the static park at the MAKS-99 airshow, with the Ka-226 prototype (RA-00199) in the background. Note the characteristic 'pantographic' towbar necessitated by the quad landing gear (above) and the partly open entry door (below).





Above: '561 Blue', the first of nine Ka-31s ordered by the Indian Navy, at a display of Kamov helicopters organised at Chkalovskaya AB. Note the ground power receptacle on the rear door.



It was this 'ironhead' version that served as the basis for an AEW helicopter designated Ka-31 (at the initial design stage the helicopter was known as the Ka-252RLD or Ka-29RLD, the suffix standing for *rahdiolokatsionnyy dozor* – radar picket). Designed primarily as a shipboard helicopter, it was to be part of the air wing of *Kuznetsov* class aircraft carriers and was intended for use in scenarios where using large AWACS aircraft was inadvisable; its intended mission was to detect low-flying targets, including anti-ship missiles, and surface ships at long range. The Ka-31's integrated mission avionics suite built around a powerful 360° search radar was to auto-detect and track targets, determine their status as 'friendly' or 'hostile' by means of the built-in IFF feature and transmit target data to shipboard or shore-based C³I centres. The helicopter was to be capable of operating in any season, around the clock, in IMC and VMC. It was to enhance the combat efficiency of Naval Aviation, Air Force, Navy and armour units by supplying them with accurate and timely information on the actions of adversary ships, strike aircraft and attack helicopters.

Design work on the Ka-31 started in 1985, and the project passed the mock-up review commission successfully the following year. This time it was not NPO Vega-M but the Nizhny Novgorod Electronic Equipment Institute (NNIIRT – *Nizhegorodskiy nauchno-issledovatel'skiy institut radioelektroniki*) that was responsible for the mission avionics. This establishment created the E-801 *Oko* (an archaic word for 'eye', or 'orb') suite built around a decimetre-waveband pulse-Doppler radar of the same name, and the suite was put through its paces on a heavily modified Ka-27 in late 1987. The work was supervised by Deputy Chief Designer S. N. Fomin.

For obvious reasons the search radar antenna can only be located ventrally on an AEW helicopter, which means it has to be retractable in order to provide adequate ground clearance when the aircraft is parked. Different approaches have been pursued when solving this task. The Westland Sea King AEW.2 and AEW.7 (ASaC.7) has the antenna in a thimble-shaped inflatable radome made of Kevlar fabric on the starboard side of the fuselage; the radome pivots about 80° aft on an L-shaped transverse axle before landing, deflating in so doing. The French Army's version of the Eurocopter AS.532M Super Puma equipped with the Orchidée radar has the antenna array in an elongated boxy housing that swings aft through 90° on a trailing arm when not in use to lie horizontally under the tailboom at right angles to the direction of flight. The Soviet designers, however, did not copy either approach but created a different concept. The Ka-31 has a flat-plate rectangular antenna



Front view of Indian Navy Ka-31 '562 Blue' (the last two digits are repeated on the dielectric fairing), showing the offset position of the stowed radar antenna. Note the open entry door with cable handrails.

running almost the full length of the fuselage. It lies flat against the fuselage underside when not in use, swinging down through 90° along the inboard side on a system of levers as it deploys and then beginning to revolve.

Of course, the landing gear needs to get out of the way before the radar is switched on to avoid reducing the field of view (or even hampering the antenna's rotation). The Sea King and the Super Puma have a retractable landing gear as standard but the Ka-29 does not. Hence the Ka-31 received a semi-retractable landing gear similar to that of the Ka-25Ts over-the-horizon (OTH) targeting helicopter. The nose gear units received a track increased from 1.4 m (4 ft 7 $\frac{1}{4}$ in) to 2.41 m (7 ft 10 $\frac{1}{2}$ in) to provide room for the radar antenna and retracted aft into narrow sponsons on the fuselage sides; the main units folded upwards against the fuselage sides when the sloping shock absorber struts jackknifed by means of hydraulic rams.

Other structural changes to the fuselage were necessitated by the need to accommodate the mission equipment and an adequate fuel supply. The full-height fuel tank containers were level with the sides of the widened cockpit section, stretching as far back as the main gear units. The 7.62-mm (.30 calibre) GShG-7.62 four-barrel Gatling machine-gun hidden under a hinged door in the Ka-29's nose was deleted, as was the undernose sighting system for unguided rockets and anti-tank guided missiles.

To cater for the power requirements of the mission avionics the standard AI-9V APU gave place to a much more powerful TA-8K APU developed by the Stoopino Machinery Design Bureau (SKBM), a version of the APU fitted to the Tu-134A/B airliner. The new APU was also much larger and hence was mounted lengthwise rather than transversely, with lateral air intake ports and an aft-mounted exhaust pipe canted to starboard.



Above and below: Indian Navy Ka-31 '565 Blue' sits at Bangalore during the Aero India-2004 airshow, the crew's 'bone dome' helmets looking like eyeballs. The Navy titles are in English to port and in Bengali to starboard.



The two prototypes were converted from stock Ka-29 airframes at the Kamov OKB's experimental production facility in Ukhtomskaya just outside the Moscow city limits, receiving the tactical codes '031 Blue' (c/n 03D1) and '032 Blue' (c/n 03D2). The second prototype outwardly differed from the first one in having additional boxy fairings low on the fuselage sides. Initial flight tests revealed that, although all these extra fairings altered the helicopter's aerodynamics, the Ka-31's behaviour in the take-off and landing modes did not deteriorate; in fact, the machine was more stable in these modes than the Ka-27.

In a futile attempt to conceal the Ka-31's military nature and pass it off as weather research aircraft, the second prototype originally wore the Soviet flag on the fins and Aeroflot/Ghidromettsentr (Weather Research Centre) titles. In this guise the helicopter entered state acceptance trials, Stage A of which took place at an instrumented test range on the Crimea Peninsula in the Ukraine. At this stage test pilots V. P. Zhooravlyov, L. P. Novikov and A. B. Poozanov verified the process of transmitting target information to shore-based command centres and to the aircraft carrier.

Stage B of the state acceptance trials began in 1991, the second prototype being stationed aboard the carrier *SNS Fleet Admiral Kuznetsov* at this stage. This is where the evolutionary approach selected by the Kamov OKB in developing the Ka-31 paid off; since the helicopter was based on proven mechanical components and a proven airframe, the test personnel could concentrate on refining the E-801 mission equipment, communications and navigation equipment.

Now that we mention it, the E-801 is highly automated. Once the landing gear has been retracted, the radar set switched on, the radar antenna deployed and the required operational mode selected by the operator, everything that follows is automatic. The radar automatically detects and tracks any target coming within detection range, determines its co-ordinates, IFF status ('friendly' or 'hostile'), vector and speed; this information is then distributed to command centres and interceptors via secure data link. On the radarscope the target appears as a 'blip' with a number allocated, accompanied by its details (co-ordinates, distance and speed). All the navigator/operator has to do is monitor the mission equipment suite's operation and keep an eye on the target 'blips'.

The radar is capable of detecting and tracking small targets (such as cruise missiles) flying within a wide altitude envelope, including ultra-low altitudes. Thus the Ka-31 makes it possible to distribute targets more efficiently between available air defence assets. The E-801 is also good against small



Above: The cockpit glazing. Note the rear view mirrors and the 'seesaw' design of the port windshield wiper which serves the port and centre windshield panels.



The jettisonable cockpit escape windows can be slid open slightly for ventilation or direct vision. Note how the towbar is connected to the scissor links of the semi-retractable nose gear units.



Above left: The rotor mast, showing the blade folding hinges and the push-pull rods connecting the upper/lower rotors to the swashplate. Note the annular gap around the engine jetpipes to let out cooling air. Above right: The starboard main gear unit, showing the retraction jack at the front of the sloping shock strut.



Rear view of the Ka-31, showing the strut-braced horizontal tail and the profusion of antennas and aural on the tailboom. The ventral box houses the antennas of the DISS-32 Doppler speed and drift sensor.

maritime targets, regardless of the sea state. In automatic mode the radar can detect a fighter-type target at 100-150 km (62-93 miles) range or a fast patrol boat-type vessel at 250 km (155 miles) range, determine the parameters of their travel and feed the information to shore-based command centres or airborne command posts. Up to 20 aerial targets can be tracked at any time.

By creating the Ka-31, the Kamov OKB solved the important problem of expanding the AEW coverage zone of own ships by means of shipboard assets from 10-15 km (6.2-9.3 miles) to 300-350 km (186-217 miles), a problem that loomed large in front of the Russian Navy. The Ka-31 can also provide OTH targeting for ships launching missile attacks. Its versatility makes it suitable also for land theatres of operations (including mountain areas) and is one of its indisputable strengths. The helicopter can operate from semi-prepared helipads right next to mobile missile systems, providing OTH targeting for the latter; in this capacity it exceeds by far the capabilities of ground OTH radars whose efficiency depends heavily on the condition of the troposphere. The Ka-31 can also be used for coast guard duties and civil applications (ATC and SAR). With a crew of two, it is 15-20 times cheaper to operate than a full-size AWACS aircraft with a crew of 17-20.

The trials were completed successfully in 1995. By then photos of the second prototype aboard the *Fleet Admiral Kuznetsov* had gained wide circulation (so much for the weather research legend – what do they want with a 'civil weather research aircraft' aboard a very military ship?), but it was in 1995 that the Ka-31 had its real public debut. On 22nd-27th August '031 Blue' was displayed at the MAKS-95 international airshow in Zhukovskiy, wearing an overall grey naval camouflage scheme and red star insignia. The helicopter was displayed both statically (with a second E-801 radar antenna arranged alongside for clarity) and in flight. However, the first demonstration flight ended in embarrassment. Sure enough, the Ka-31 looked impressive as it made a slow pass with the huge slab-like antenna deployed and rotating (not to mention the very distinctive clatter emitted by the helicopters of the Ka-27 family), but when it was time to land, something went wrong and the antenna would not stow fully. Hence at the MAKS-97 airshow (19th-24th August 1997) Ka-31 '031 Blue' stayed firmly on the ground. The static park at the MAKS-99 (17th-22nd August 1999) included Ka-31 '032 Blue', now repainted in full military livery at last.

In 1998 the Ka-31 entered low-rate production at KumAPP. However, deliveries to the Russian Navy were virtually non-existent due to financial constraints: it was hard enough to keep the *Kuznetsov*'s existing carrier wing



Above: Another view of the tail unit, showing the fixed leading-edge slats preventing airflow departure from the fins in a crosswind.

of Sukhoi Su-33 fighters flying! Thus, to everyone's surprise India emerged as the launch customer for an aircraft which was not yet in service in the country of origin. In August 1999 it was announced that the Indian Navy had ordered four such machines; three of them were to be deployed aboard Soviet-built destroyers known by the NATO reporting name 'Krivak III', while the fourth was to be based aboard the aircraft carrier *INS Viraat*. The initial contract was worth US\$ 92 million. Eventually the Indian Navy increased its order to nine Ka-31s, although Kamov Co General Designer Sergey Mikheyev had said in an

interview on 18th August 1999 that India would buy 'at least ten'. Twelve Ka-31s were operational as of July 2004.

The Ka-31 in Detail

Type: Shipboard tactical airborne early warning helicopter designed for day/night operation in VMC and IMC. The airframe is of all-metal construction and is mostly made of aluminium alloys.

Fuselage: Conventional all-metal semi-monocoque structure of riveted construction



The doors on the rear fuselage underside which hide the dunking sonar on the Ka-27PL are used for access to the avionics bay on the Ka-31. The doors proper have been removed in this photo of '032 Blue'.



The cockpit of the Ka-31, with the pilot's seat on the left and the navigator/radar operator's workstation (with centrally mounted radarscope) on the right.

with frames, longerons and stringers. Structurally the fuselage consists of four sections: forward fuselage, centre fuselage, tailboom and engine/gearbox housing. The tailboom is detachable for heavy maintenance or transportation by road/rail.

The *forward fuselage* is the extensively glazed cockpit. It features three windshield panels, two sidelights and two sliding side windows; the latter can be jettisoned for emergency evacuation. All glazing panels are optically flat to avoid view distortion; the port and starboard windshield panels directly in front of the pilots are equipped with wipers and electrically de-iced. A full-width GRP nose fairing and a forked pitot boom offset to port are located below the windshield.

The cockpit roof incorporates a forward-hinged hatch opening outwards for maintenance access to the engines and rotor head. The forward fuselage features sponsons for the nose landing gear units that continue aft to the centre fuselage.

The *centre fuselage* is the main load-bearing part of the airframe to which the forward fuselage and tailboom are attached; it tapers towards the rear (aft of the cabin) to mate with the tailboom. The former troop/cargo cabin of the Ka-29 houses the mission avionics and is flanked by fuel tank containers equal in width to the flightdeck section (they are 500 mm/1 7/8 in wider than the rest of the centre fuse-

lage) and the rear parts of the nose gear sponsons. Crew access is via a narrow horizontally split door to starboard just aft of the cockpit; the upper and lower halves open independently and the lower half incorporates boarding steps. A large aft-sliding door to port at the rear serves for access to the avionics. The centre fuselage underside features a cutout for the radar antenna turntable, antenna retaining locks at the front and rear and clamshell doors for avionics bay access.

The *tailboom* is a stressed-skin structure of oval cross-section with the larger axis vertical, tapering gently towards the end; it accommodates control rods and carries the tail unit, as well as communications and radio navigation aerials.

Tail Unit: Twin-fin strut-braced tail unit of all-metal stressed-skin construction. The *vertical tail* consists of two fins and one-piece rudders having a trapezoidal planform. The fins are set at a strong toe-in angle and feature fixed leading-edge slats. The fixed-incidence constant-chord *horizontal tail* of trapezoidal planform has no control surfaces.

Landing Gear: Semi-retractable quad type, with single wheel on each unit; hydraulic actuation and free-fall extension in emergency. All units have oleo-pneumatic shock absorbers.

The castoring levered-suspension nose units retract aft so that the wheels are semi-recessed in narrow lateral sponsons. Each main unit comprises a vertical strut with a fork for the wheel, two pairs of rods hinged to the fuselage and the strut to form two triangle braces above one another, and a sloping upper strut incorporating a shock absorber. The upper struts have a snap-action design and fold by means of hydraulic rams, pulling up the main gear units against the fuselage sides, the main units remaining completely exposed.

Powerplant: Two Izotov (NPP Klimov) TV3-117VMA turboshafts with a nominal rating of 1,700 eshp (1,267 kW) and a take-off/contingency rating of 2,500 eshp (1,864 kW). If one engine fails the other automatically goes to full take-off power.

The TV3-117 is a single-spool turboshaft with a 12-stage axial compressor, an annular combustion chamber with 12 flame tubes, a two-stage axial turbine, a two-stage free turbine and an angled jetpipe through which the power output shaft passes. The first five compressor stages feature variable inlet guide vanes; two anti-surge bleed valves are installed aft of the seventh compressor stage.

The engine has a dorsally-mounted accessory gearbox. Starting is by means of an SV-78B air starter (*startyor vozdooshnyy*) connected to the gearbox. The engine has its

own oil system using grade B-3V synthetic oil which permits starting at ambient temperatures right down to -40°C (-40°F).

The engines are installed side by side on top of the centre fuselage (ahead of the gearbox), parallel to the fuselage axis. The port and starboard engines are interchangeable, except for the detachable handed jetpipes incorporating tunnels for the output shafts.

The Ka-31 is equipped with a Stoopino Machinery Design Bureau TA-8K auxiliary power unit aft of the main gearbox for engine starting, ground power supply and air conditioning; the APU also serves as the main power source for the mission avionics. Unlike the Al-9V fitted to the Ka-29, it can run for long periods of time, ensuring an uninterrupted power supply even during long missions.

The TA-8V has a single-stage centrifugal compressor, a single-stage peripheral turbine, a 12-kW GS-12TO DC starter/generator and a GT40PCh6 AC generator. Dimensions, $1.368 \times 0.701 \times 0.717 \text{ m}$ (4 ft 5 $\frac{1}{2}$ in \times 2 ft 3 $\frac{1}{2}$ in \times 2 ft 4 $\frac{1}{2}$ in), dry weight with generator 216 kg (476 lb). Bleed air pressure 3.3 bars (47 psi), delivery rate 0.75 kg/sec (1.65 lb/sec), equivalent power 107 kW, fuel consumption 145 kg/h (320 lb/h). The APU can be started at altitudes up to 5,000 m (16,400 ft).

Powertrain: Engine torque is fed via overrunning clutches into the VR-252 multi-stage gearbox mounted on a truss-type bearer. Apart from conveying torque to the rotors, the gearbox also drives various accessories (two generators, an AK-50T1 Srs 11 compressor, two hydraulic pumps and more). The gearbox has an independent oil system. The rotor shafts are inclined $4^{\circ}30'$ forward. A shoe-type rotor brake is provided to minimise rundown time after engine shutdown and to lock the rotors during parking or maintenance.

The engines, APU and gearbox are enclosed by a common fairing with hinged cowlings, some of which act as work platforms during maintenance.

Rotor System: Two fully articulated co-axial rotors; the upper rotor turns clockwise when seen from above and the lower rotor anti-clockwise. The blades feature an all-composite construction with carbonfibre and GRP spars and 13 trailing-edge pockets of a material similar to Kevlar, with a filler similar to Nomex. The blades are fitted with balance tabs used for adjusting the main rotor. The blades utilise an asymmetrical airfoil and feature balance tabs; the lower rotor blades have dependent weights at the roots acting as vibration dampers, and there are further dampers in the fuselage.

The blades are equipped with an electric de-icing system operating at all times when the engines are running. The upper rotor

blades have tip recognition lights.

The main rotor head is manufactured of 50% titanium and 50% steel. It features a classic layout with feathering, flapping and drag hinges. To save deck/hangar space all blades can be folded aft manually and secured by a special clamp system attached to the tailboom.

Control System: Fully powered controls without manual reversion, with push-pull rods and bellcranks throughout; the hydraulic control actuators are combined into a single RS-60 unit. Pitch and roll control, as well as climb/descent, are effected by the swashplate. Directional control at the hover and low speed is effected by changing the pitch of the upper and lower rotors differentially; directional control in forward flight is effected by the rudders.

Fuel System: Fuel is carried in 14 tanks filled with explosion-suppression polyurethane foam; tanks Nos 1-4 are self-sealing. The APU uses its own pair of tanks (Nos 7). Total fuel capacity is 3,060 litres (673.2 Imp gal). Fuel grades used are Russian T-1, TS-1 or T-7P jet fuel (T = toplivo) or Western equivalents (JP-1 or JP-4).

Hydraulics: Three separate hydraulic systems (main, backup and auxiliary) which power the control surface actuators. All systems use AMG-10 oil-type hydraulic fluid. The main and backup systems are powered by NP92A-5 variable-capacity plunger-type pumps driven off the gearbox, while the auxiliary has an electrically-powered pump unit and a hand-driven pump. Operating pressure 64-90 kg/cm 2 (914-1,285 psi)

Electrics: Five electric systems operating the avionics, the de-icing system, fuel system components, radar antenna drive mechanism and other equipment.

Primary 200V/115V/ 400 Hz three-phase AC is supplied by two GP-23 generators driven off the gearbox. Other systems use 115V/400 Hz single-phase AC, 36V/400 Hz three-phase AC (supplied by two T-1 step-down transformers) and 27V DC. The main source of DC power is two VU-6B rectifiers, with 27V (25 A-h) DC batteries as a back-up. The APU drives a GT40PCh6 AC generator forming part of an independent power supply system catering for the E-801 mission avionics suite.



Above: The second prototype's radar antenna in stowed position, showing the suspension/actuation mechanism. Note also the underside of the lateral sponsons with recesses for the nosewheels.



The aircraft's radar antenna in deployed position, showing the four strings of 24 emitters each. Note the twin landing lights ahead of the antenna.

All systems operate in parallel, each using its own group of distribution buses. Overload protection devices automatically exclude a failed power source or damaged section of circuitry.

A 27V DC ground power receptacle is provided on the port side of the rear fuselage.

Avionics and Equipment

Flight/navigation equipment: The flight/navigation suite comprises an autopilot, a PKP-77 flight director (*pilotazhno-komahndnyy pribor*), a PNP-72-15 gyro horizon (*plahnovo-navigatsionnyy pribor*), an IK-VK directional and vertical gyro data system (*informatsionnyy kompleks vertikal'nyy i koorsa*), an IK-VSP-V1-2 altitude and speed data system (*informatsionnyy kompleks vysotno-skorosnykh parametrov*), a DISS-32 Doppler speed/drift sensor (*doplerovskiy izmeritel' skorosti i snosa*), an A-036A radio altimeter, an ARK-22 automatic direction finder (*avtomaticheskoye radiokompas* – ADF), an A-723 long-range navigation (LORAN) system and an A-380 short-range navigation (SHORAN) system. The suite further includes an AGR-74V-10 artificial horizon, range and speed indicators, a navigation computer and other components.

The flight/navigation suite works in conjunction with the RS-60 control actuator unit, the master caution/warning system, the FDR, the communications suite, the fuel metering system, the mission avionics and the ship's navigation suite.

The flight/navigation suite enables automated flight and caters for the following flight management tasks:

- automatic course/pitch stabilisation and automatic damping of the helicopter's angle oscillations;

- automatic stabilisation of true or barometric altitude;

- automatic turn onto a preset course and stabilisation of this course when following a pre-set route;

- an automatic 'go-to' function for return to the base/the ship or the landing decision point, using signals generated by the base's (or ship's) radars;

- generation of signals permitting control in flight director mode;

- initiation of descent and stabilisation of the required descent gradient;

- autostabilisation in the hover, using signals generated by the Doppler speed/drift sensor and radio altimeter;

- automatic course/pitch stabilisation when the radar antenna is deployed, using sensors indicating the antenna's angle relative to the fuselage;

The navigation tasks performed by the system include:

- automatic independent computation and indication of the helicopter's current co-ordinates in inertial/Doppler, inertial, course/Doppler and course/air data system modes, using the geographical and orthodromic systems and switching automatically between the modes;

- automatic computation of the bearing and range with respect to shipboard or shore radio beacon, with co-ordinate correction when the SHORAN system comes into play;

- automatic computation of the helicopter's current co-ordinates, using the LORAN system;

- computation of navigation parameters for following a route with up to eight waypoints, with provisions for altering the route promptly;

- following a pre-programmed route and returning to the point of origin;

- following standard courses during on-station loitering;

- automatic real-time computation of the base ship's current co-ordinates, using the data link system and communications suite or, in OTH conditions, using the ship's memorised course and speed.

Communications equipment: The Ka-31's communications suite ensures air-to-air and air-to-ground/air-to-ship communication in unscrambled or secure mode and transmission of target information. The suite functions in LF (voice link), HF (metre-waveband) and VHF (decimetre-waveband) modes. At a flight altitude of 1,500-3,500 m (4,920-11,480 ft), reliable data link is guaranteed at a range of at least 150 km (93 miles).

Mission avionics: The Ka-31 is equipped with an E-801 Oko early warning suite developed jointly by NNIIRT and the Kamov OKB. It enables detection of surface ships at up to 250 km and aerial targets (including low-flying ones) at up to 200 km, their identification and

target data transmission to shipboard and shore-based C³I centres. The suite is built around a two-co-ordinate search radar and an active IFF system; it works in conjunction with the flight/navigation suite and the communications suite.

The E-801 decimetre-waveband radar provides 360° coverage with a scanning time of ten seconds, fully automatic and semi-automatic target detection, target co-ordinate computation and tracking/trajectory computation. Its antenna array is installed into a flat rectangular metal structure 6 m (19 ft 8½ in) long and 1 m (3 ft 3½ in) wide suspended on an electrically powered turntable under the fuselage. When not in use the antenna is aligned with the fuselage axis and stowed to lie flat against the fuselage underside.

The receiver system comprises an HF receiver, an active ECM locator, a coherent processor module, target radial speed measurement and false alarm elimination modules, a signal filtering and post-detector processing system, and an initial processing module. The transmitter generates radar pulses in the required waveband.

The received signals are fed into a data processing system which includes a digital computer, control signal generators, an IFF interrogator and an interface with the communications suite. The radar can track twenty (if target data is relayed in real time) or forty targets at a time. Detection range is from 100 to 150 km (62-93 miles) for a fighter/helicopter-type target and 250 km (155 miles) for a surface ship. The processed information on the number of targets and their speeds and routes is transmitted via data link to both shipboard and shore-based C³I centres.

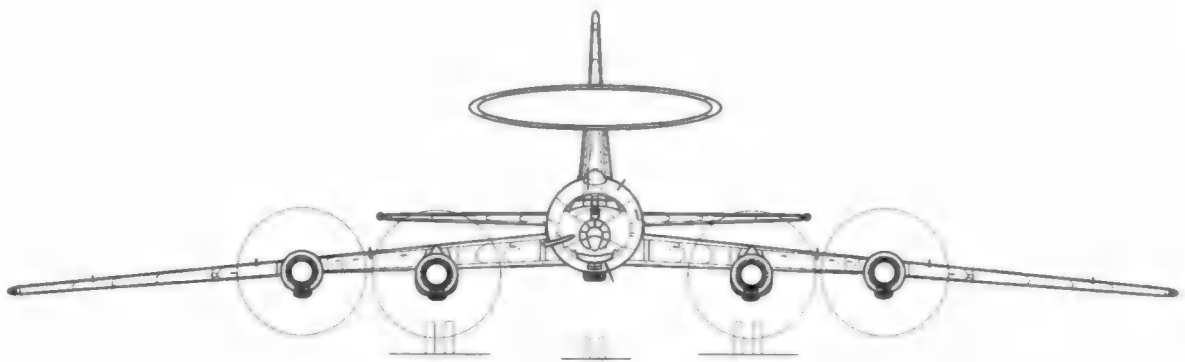
The mission avionics have an independent power supply system; on the other hand, the radar antenna tilting and traversing mechanism is powered by the helicopter's primary electric system. If the antenna jams in the deployed position and cannot be stowed, it may be jettisoned pyrotechnically to permit a safe landing. This is triggered by pushing a button of the collective pitch lever or by jettisoning the flightdeck emergency escape windows.

Data recording equipment: Tester-3 flight data recorder to facilitate debriefing or accident investigation.

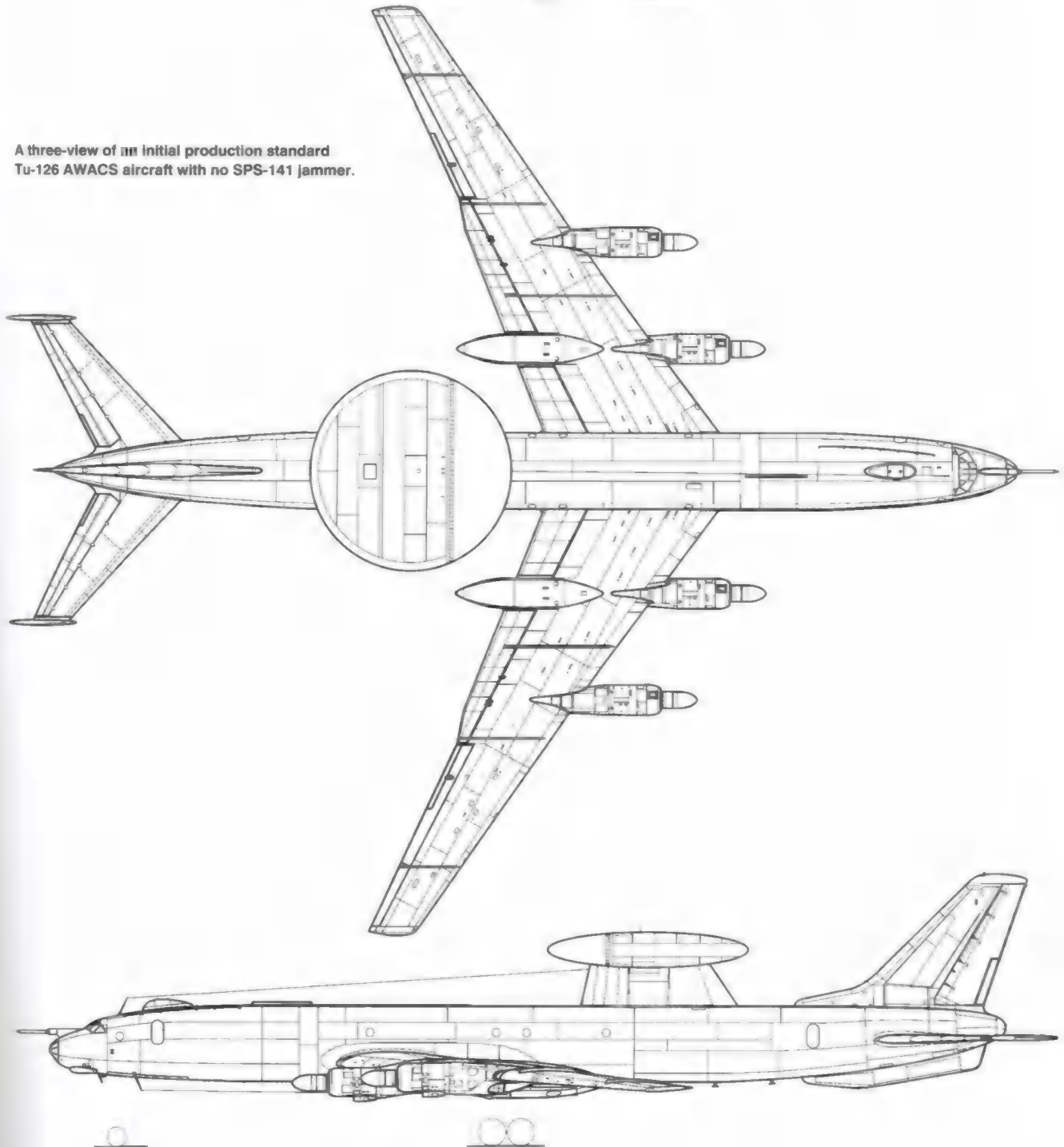
Exterior lighting: BANO-45 port (red) and starboard (green) navigation lights on the outer faces of the fins, KhS-39 white navigation light on the tailboom. Red MSL-3 rotating anti-collision beacons on top of the APU cowling and under the cockpit. Two retractable MPRF-1A landing/taxi lights under the nose. Two EKSP-39 electric flare launchers on the starboard side of the rear fuselage; each launcher fires four 39-mm (1½-in) signal flares (red, green, yellow and white).

Ka-31 main specifications

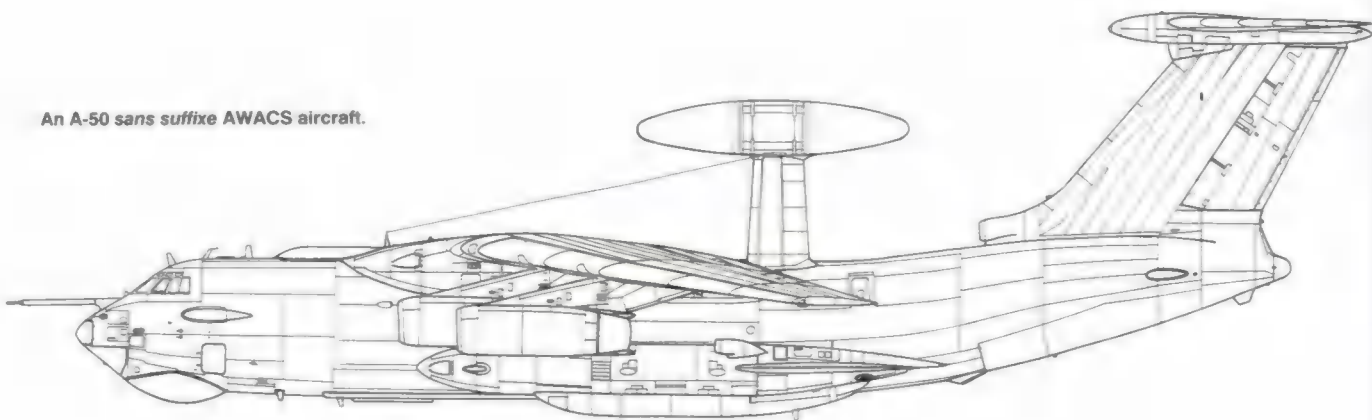
Crew	2
Length, rotors folded	12.5 m (41 ft 0 in)
Fuselage length, less pitot	11.25 m (36 ft 10¾ in)
Height on ground, top of rotor mast	5.6 m (18 ft 4¾ in)
Fuselage width	3.8 m (12 ft 5¾ in)
Landing gear wheelbase	3.05 m (10 ft 0 in)
Nose gear track	2.41 m (7 ft 10¾ in)
Main gear track	3.5 m (11 ft 5¾ in)
Rotor diameter	15.9 m (52 ft 1¾ in)
Take-off weight, kg (lb)	12,500 (27,560)
On-station loiter speed, km/h (mph)	100 (62)
On-station loiter time, hours	2.5
On-station loiter altitude, m (ft)	3,500 (11,480)
Effective range with maximum fuel and the radar antenna stowed, km (miles)	600 (372)



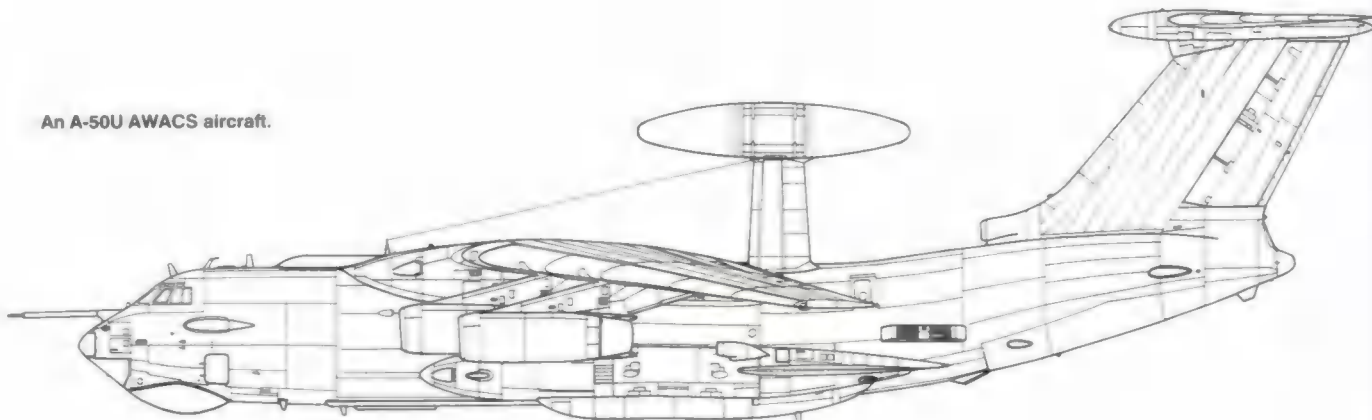
A three-view of the initial production standard Tu-126 AWACS aircraft with no SPS-141 jammer.



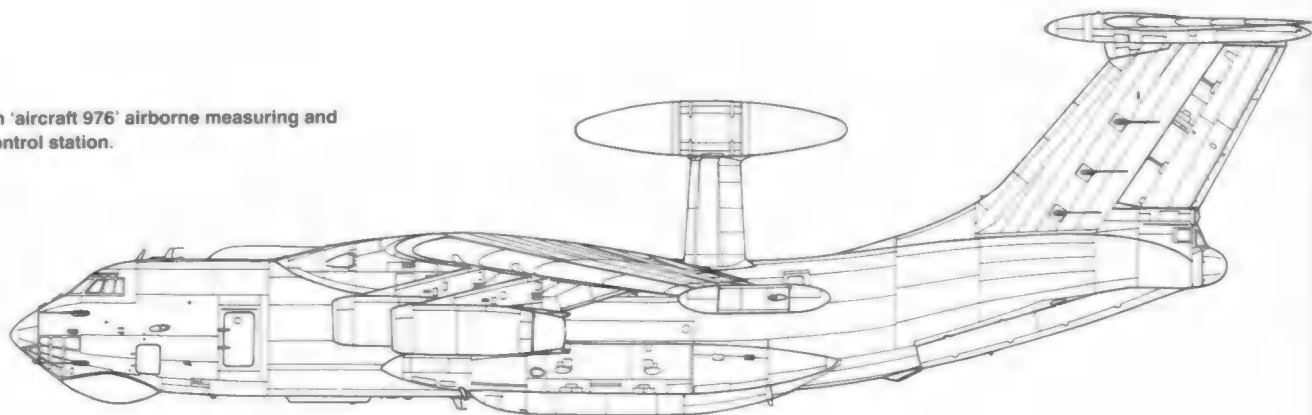
An A-50 sans suffixe AWACS aircraft.



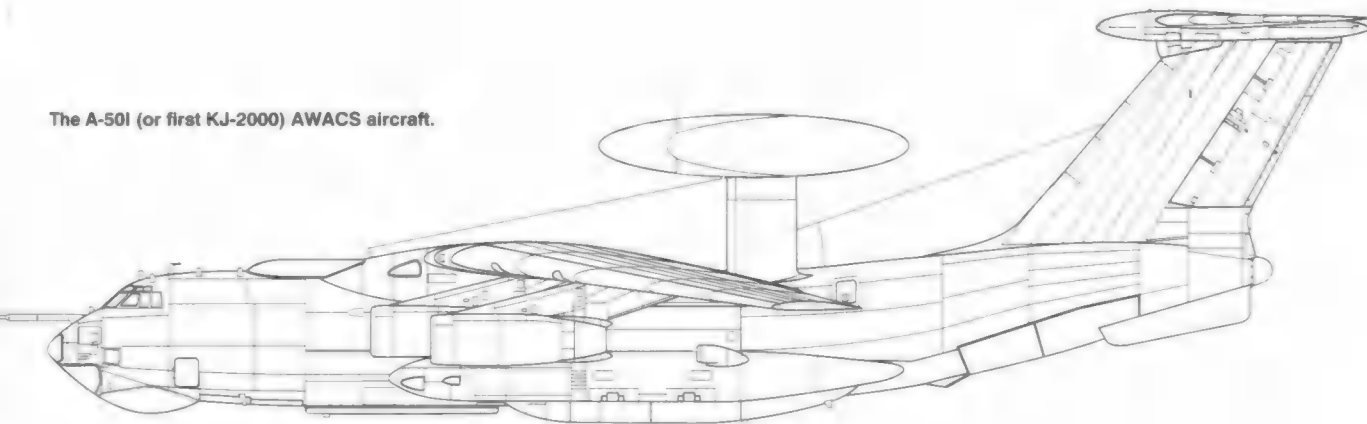
An A-50U AWACS aircraft.



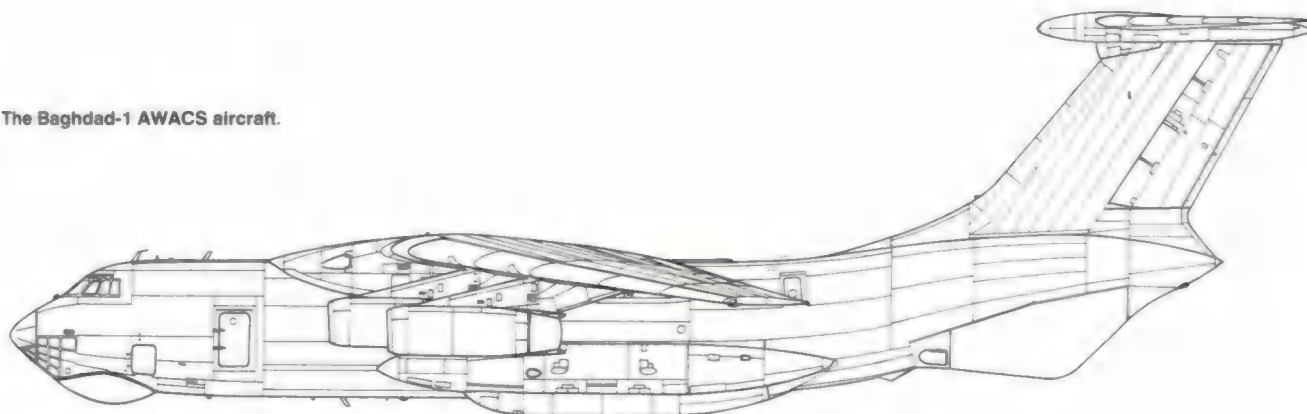
An 'aircraft 976' airborne measuring and control station.



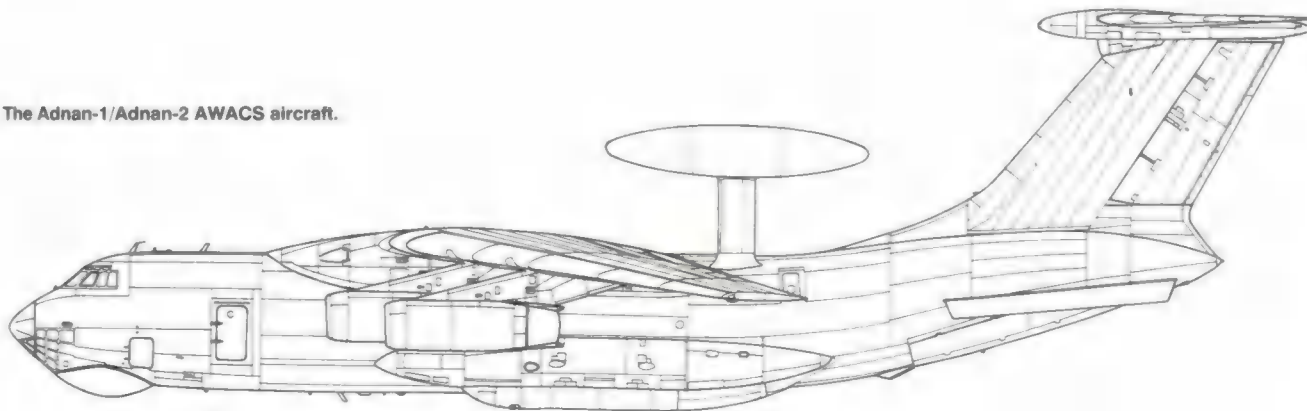
The A-50I (or first KJ-2000) AWACS aircraft.

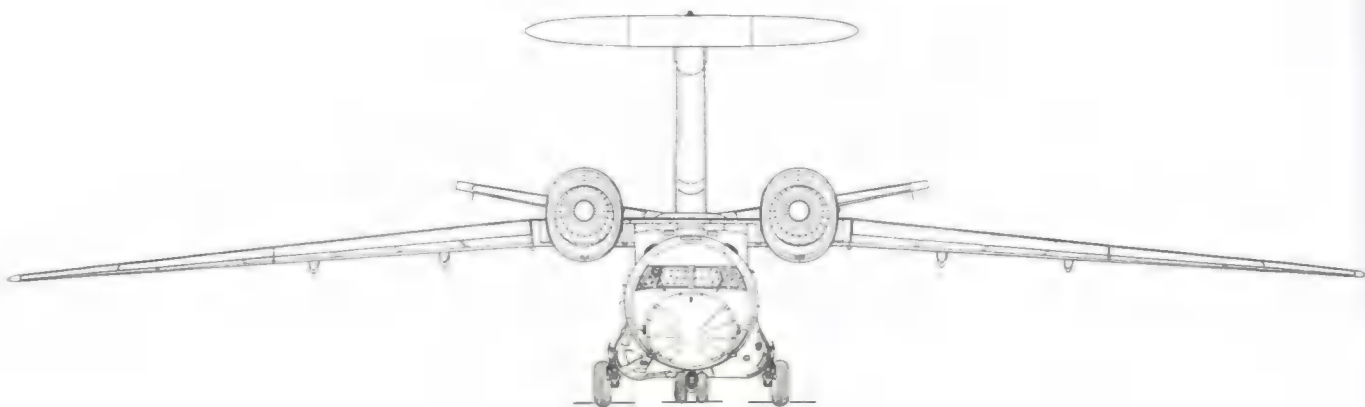


The Baghdad-1 AWACS aircraft.



The Adnan-1/Adnan-2 AWACS aircraft.

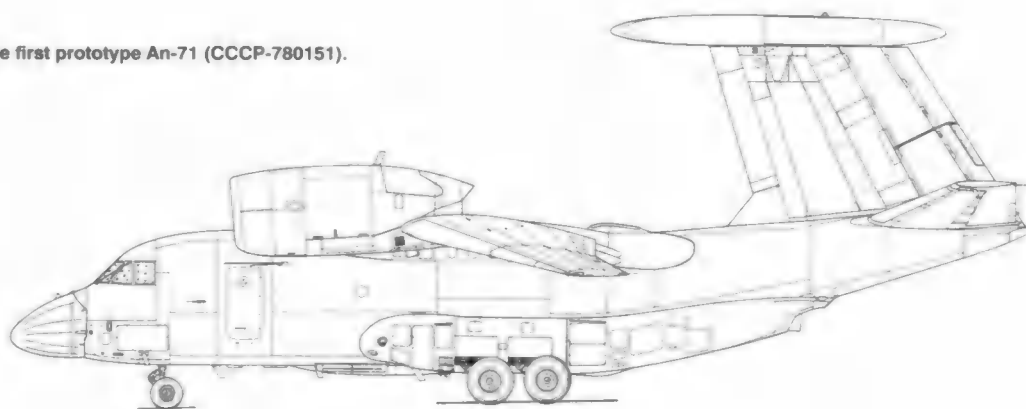




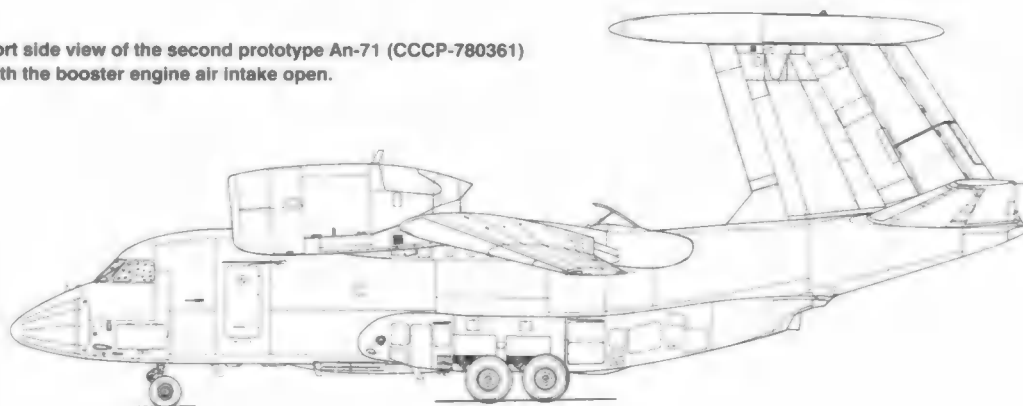
Front and plan views of the second prototype An-71 AWACS aircraft.



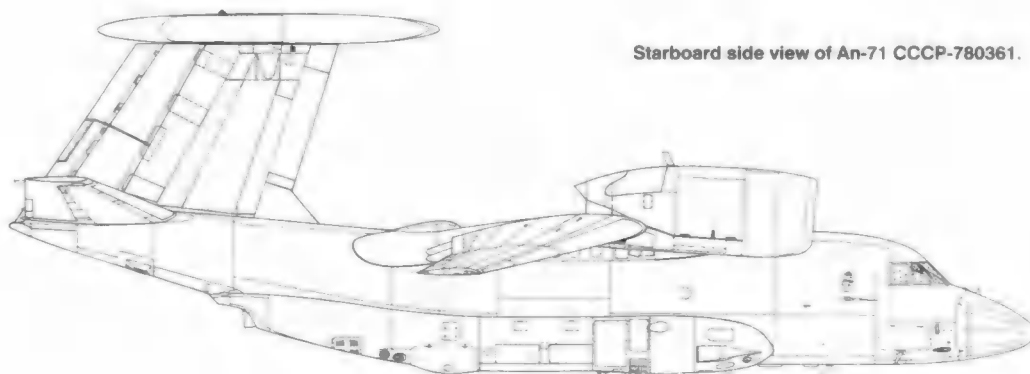
The first prototype An-71 (CCCP-780151).



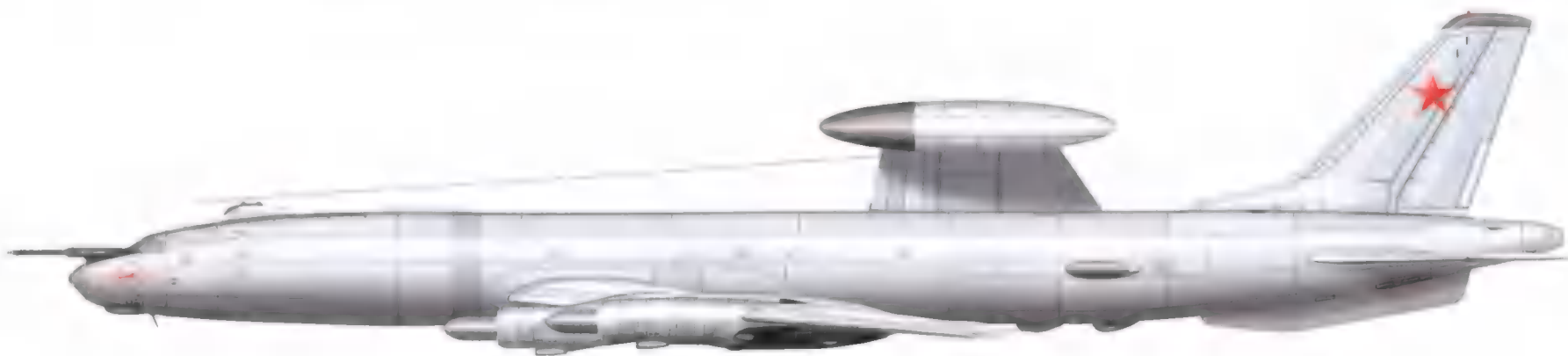
Port side view of the second prototype An-71 (CCCP-780361) with the booster engine air intake open.



Starboard side view of An-71 CCCP-780361.



A late-production Tu-126 with ■■ SPS-141 jammer in the tailcone and an 'Excellent aircraft' maintenance award badge on the nose.



The second prototype An-71. The two drawings ■■ not to scale.





Above: The hulk of the Tu-126LL (alias LL '2A') on the dump at Zhukovskiy in the early 1990s; note the empty test equipment pod at the starboard wingtip. The tail of the IL-18SIP telemetry pickup aircraft (CCCP-27220) is visible on the left. Both have now been scrapped.



A model of the 'Soviet E-3' that never materialised – the Tu-156.



The third prototype A-50 sans suffixe ('20 Red', c/n 0013430875, f/n 2209) on the runway at Taganrog.



Above: A-50 sans suffixe '33 Red' (c/n 0043454618, f/n 4105) is caught by the camera a few seconds before touching down at Ivanovo-Severnnyy AB.



A-50 sans suffixe '41 Red' (c/n 0083483499, f/n 6305) applies reverse thrust after landing at Kubinka AB, passing two of the resident (and non-airworthy) Antonov An-12 transports.



The same aircraft at rest a few minutes later. The thrust reverser bucket doors on all four engines are open. Note the very chipped rotodome.



Above: Pristine-looking A-50 sans suffixe '42 Red' (c/n 0083484538, f/n 6405) flies high above the clouds.



Another aspect of the same aircraft as it makes a banked turn.



Above: A-50 sans suffixe '46 Red' (c/n 0033443258, f/n 3205) seen during a brief deployment to Klin-5 AB north of Moscow.



Below: side view of the same aircraft, with two of the resident machines – a Tu-134Sh-2 navigator trainer ('38 Blue') and an IL-76MD – in the background. Note the red paintwork on the forward fuselage and the chin radome.



Above: A-50 suffix '47 Red' (c/n 0043453577, f/n 4005) is manoeuvred into position by ■ KrAZ-255B-1 ■ heavy-duty lorry at Vladimirovka AB, Akhtobinsk, with ■ TZ-22 fuel bowser standing by to top up the aircraft's tanks for the next mission.



The same aircraft pictured at a later date, sharing the hardstand ■ Ivanovo-Severnnyy with at least four more A-50s and several IL-76MDs. Note the AEW&C Force badge aft of the flightdeck.



Yet another view of '47 Red' as it departs from Ivanovo-Severnnyy (prior to the application of the said badge), with more *Mainstays* and an Antonov An-26 transport in the background.



A Mikoyan MiG-31B breaks formation with an uncoded A-50 during an air event in Nizhniy Novgorod.



An atmospheric head-on shot of an A-50U taken on a winter afternoon. Judging by the plate on the wheeled ladder parked in front of the aircraft, this example may be coded '45 Red' (c/n 0093493818, f/n 7105).



Above: *Mainstay* in action. An A-50 sans suffixe flies over the foothills of the Caucasus; note the weathered and stained appearance.



An A-50  suffixe makes a rather smoky afternoon landing approach.



Above: '44 Red', the prototype A-50U (c/n 0093486579, f/n 6505) taxis at Akhtobinsk, showing the lack of the port side navigator's station window.



Another view of the A-50U prototype, showing the IRCM flare dispenser pods and the additional ECM blisters.



Above: A-50U '50 Red' (c/n 0093496899, f/n 7305) parked at Ivanovo-Severnnyy. Note the pale sectors near all six ECM blisters and the wing inspection light built into the starboard front blister; on the IL-76 this light is located on the port side and the wing is inspected through the window in the port entry door.



Another view of the same aircraft. It is fairly common practice for IL-76/A-50 pilots to apply a burst of reverse thrust when taxiing in and then shut down the engines, leaving the thrust reverser bucket doors open.



Above: A-50U '51 Red' (c/n 1003488634, f/n 6609) climbs away from Ivanovo-Severnnyy as the landing gear begins its retraction sequence.



The same aircraft parked at its home base. The canvas cover has slipped from the flightdeck glazing. Note the solidly built jet blast deflector behind the aircraft.



Above: A-50U '51 Red' in a picture-perfect wedge formation with four Su-27Ps from the Russian PVO's 148th Combat & Conversion Training Centre at Savasleyka AB. The fighters sport a shield with St. George and the Dragon superimposed on a large Russian flag on their tails.



A-50U sits at Taganrog in company with a Tu-142MZ ASW aircraft (background) and one of the Beriyev A-40 ASW amphibians. Judging by the removed rotodome lying alongside, the aircraft is due for some upgrade work



Above: The A-50I prototype (the future RA-78740) flies over the suburbs of Taganrog during manufacturer's flight tests.



Another air-to-air of the A-50I over Taganrog.



Above: One more view of the A-50I in an early test flight. The ventral strakes appear to be unpainted (in chrome yellow primer).



'Aircraft 976' CCCP-76452 (left) and RA-76453 parked on the south side of the airfield in Zhukovskiy near the end of runway 12.



Above: 'Aircraft 976' CCCP-76453 in the static park ■ the MosAeroShow '92. Note the differently coloured front and ■ dielectric fairings of the port wing pod and the dayglo orange housing of the navigation light on the same pod.



Another view of CCCP-76453 ■ the MosAeroShow '92. Visible beyond are Tu-154LL CCCP-85083 (an avionics/aerodynamics testbed under the Buran space shuttle programme) and A-50U '51 Red'.



Above: The 'aircraft 976' makes a very distinctive picture as it comes in to land.



A beautiful shot of 'aircraft 976' 76455 on short finals to Zhukovskiy. Note that the СССР- prefix is still carried on the wings; note also that hoar frost builds up on the undersides of the outer wings where the fuel tanks full of cold kerosene are located.



Above: Front view of the second prototype An-71 on the factory apron at Kiev-Svyatoshino during the third Aviasvit-XXI airshow in September 2002. The An-71 is an unusual bird, from whichever angle you look at it.



Another view of An-71 CCCP-780361.



Above: '031 Blue', the first prototype Ka-31, on display at the MAKS-95 airshow; note that the tactical code is repeated on the dielectric nose fairing.



The second prototype at the MAKS-99 in full military markings as '032 Blue'; note the much smaller star insignia and the test equipment housing on the starboard side aft of the main gear. The anti-collision lights appear to be missing.



Above: The same aircraft, now marked '32 Blue' (the zero has been obliterated), flies with the gear up and the radar antenna stowed.



Another view of '32 Blue' in ferrying configuration. Note the reinstated air data boom with pitch/yaw vanes on the nose.



Above: '32 Blue' with the radar antenna deployed and rotating. The air data boom is mounted on the centreline.



Another view of the same aircraft as it makes a flypast. Note that the protruding ventral test equipment rack has been removed and the ventral clamshell doors reinstated.



Above: Ka-31 '561 Blue' at Chkalovskaya AB shortly before delivery to the Indian Navy.



'565 Blue', an operational Indian Navy Ka-31, at Bangalore during the Aero India-2005 airshow with an HAL Dhruv light helicopter parked beyond.



Above: Ka-31 '565 Blue' takes off for a demonstration flight at Aero India-2005.



Another view of the same machine during the demonstration flight, showing the underside details, including the tandem antennas of the DISS-32 Doppler speed/drift sensor.

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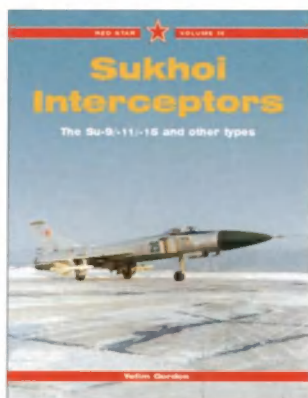
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The Su-9/-11/-15 and other types

Yefim Gordon



From 1953 Sukhoi produced a line of delta-winged interceptors including the Su-9 in 1958 followed in 1959 by the T-47/Su-11. A new line was started in 1960 with the twinjet T-58 which entered production as the Su-15. This aircraft remained a key element of the Soviet Air Defence Force well into the 1980s. Various versions of the Su-15 are detailed, as are the experimental PT-7/PT-8, T-49 and the unusual two-seat P-1 heavy interceptor.

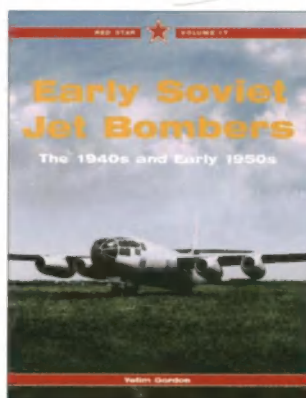
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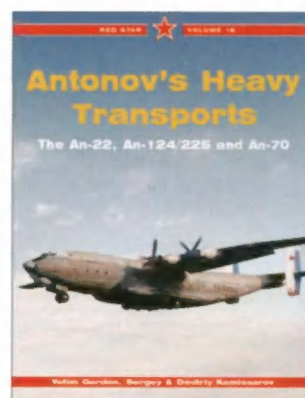
The Soviet Union put German technology to good use when developing its own jet bombers. The first to fly in the USSR was the Junkers EF131. This was followed by the EF140 and the equally unusual T-tailed, Baade 'aircraft 150'. The first wholly indigenous jet bomber was the four-engined IL-22 of 1947. Other experimental Ilyushins – the IL-30, IL-46 and IL-54 are described, as are the Tupolev 'aircraft 77', 'aircraft 82' and the 'aircraft 72/73/78' series.

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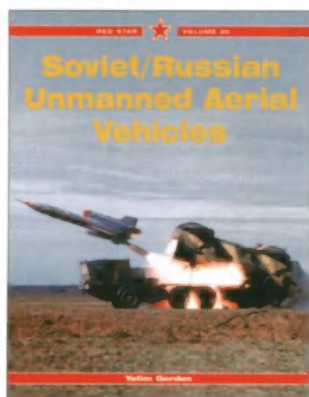


In the nervous 1950s, the Soviet Union faced the task of defending its borders against intrusions by Western spyplanes or bomber attacks. Aircraft developed for this priority long-range interception task included Mikoyan's I-3, I-7U, I-75 and Ye-152 which paved the way for the MiG-25, Sukhoi's T-37, terminated before it had a chance to fly, and Tupolev's Tu-128 – so huge it was mistaken for a medium bomber in the West.

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Red Star Volume 20 SOVIET/RUSSIAN UNMANNED AERIAL VEHICLES

Yefim Gordon



The Lavochkin OKB's La-17, produced in target drone and recce versions, was the first Soviet UAV to find large-scale use. The Tupolev OKB also developed a line of UAVs, including the Tu-123 Yastreb, Tu-141 Strizh, Tu-243 Reys and the latest Tu-300 recce/strike UAV. Yakovlev's unmanned aircraft are also covered including the Pchela (Bee) surveillance UAV. Mention is also made of UAVs and drones developed by such companies as Strela and the Moscow Aviation Institute.

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Red Star Volume 21 ANTONOV'S JET TWINS

Yefim Gordon and Dmitry Komissarov



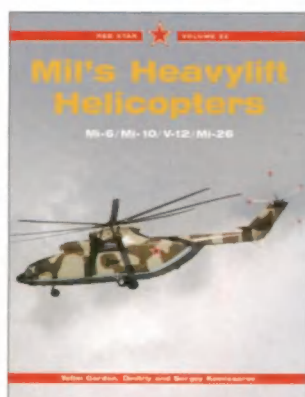
The need to provide a state-of-the-art jet successor to the An-26 led Antonov to develop a twin-turboprop tactical airlifter, the An-72, with its signature high-mounted engines, employing the Coanda effect to dramatically improve wing lift and STOL capability.

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An imprint of
Ian Allan Publishing www.ianallanpublishing.com

ISBN 1-85780-215-2



9 781857 802153

USA \$36.95 UK £19.99

Printed in England